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LUME 4 • NUMBER 5

- Kawano — Characteristics and Applications of Microwave Spark Oscillators
- Epis — Compensated Electromagnetic Horns
- Hoovler — A Nomograph for Determining Electron Gun Characteristics
- Young — Design Chart for Quarter-Wave Stubs
- Siegman — Thermal Noise in Microwave Systems — Part III

the microwave journal

ROBT H MAIER-SR ENGR
310 SOUTH EDGEWOOD AVE
LA GRANGE-ILLINOIS

In This Issue . . .

MICROWAVE SPARK OSCILLATORS

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COAXIAL TEST EQUIPMENT

INSTRUMENT	MODEL NO.	FREQ KMC/SEC	PRICE	COMMENT
SLOTTED SECTIONS	N101A N101B *V101A *V101B N110A	1.00- 4.00 4.00-10.00 1.00- 4.00 1.00- 4.00 0.20- 4.00	$470.00 $440.00 $470.00 $470.00 $550.00	Type N or C adapter connector supplied for N101A, B
FERRITE ISOLATORS	N157A	1.00- 4.00	$300.00	
FIXED ATTENUATORS	N180A,B,C,D	1.00-11.00	$ 42.00	3, 6, 10, 20 db
TUNABLE PROBES	B200A B202A	1.00-12.40 0.35- 1.40	$145.00 $225.00	1N23B supplied 1N21B supplied
DETECTOR MOUNTS Tunable Untuned	N200A N210A **N210B	1.00-12.40 0.10-10.00 0.10-10.00	$145.00 $ 50.00 $ 55.00	1N23B crystal supplied
THERMISTOR MOUNTS Broadband Temp Compensated	N215A N217A	0.50-10.50 0.50-10.50	$ 75.00 $140.00	Z215L element supplied
THERMISTOR HEAD	N218A	0.01-10.00	$145.00	Used with Model B831A
DOUBLE STUB TUNER	N300A	1.00-10.00	$ 90.00	
SLIDE SCREW TUNER	N311A	1.00-10.00	†	
FREQUENCY METERS, DIRECT READING	N410A N414A	1.00- 4.00 4.00-11.00	$495.00 $495.00	Accuracy 0.08% Accuracy 0.10%
DIRECTIONAL COUPLERS (20 DB)	N616D N617D	0.25- 1.00 1.00- 4.00	$160.00 $150.00	
KLYSTRON TUBE MOUNT	N761A		$ 95.00	Z761P cable not supplied
KLYSTRON TUBE MOUNT	Z762B		$145.00	Z762P cable supplied

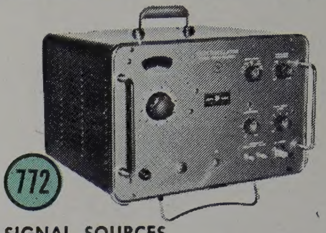
*Mating coax dim. 7/8" all others 3/8"

**Model N210B has built in DC return.

†Price will be furnished on request.

WAVEGUIDE TEST EQUIPMENT

Y .622x.311	K* .420x.170	U* .280x.140	Q .224x.112	M .148x.074	E 122x.061	F .080x.040	G .051x.0255	FXR SERIES PREFIX WAVEGUIDE SIZE IN INCHES (I.D.)
12.40x18.00	18.00-26.50	26.50-40.00	33.00x50.00	50.00-75.00	60.00x90.00	90.00-140.00	140.00x220.00	FREQUENCY RANGE IN KMC/SEC
Y102A $545	K102A $545	U102A $545	Q103A $1100	M103A $995	E103A $1650	F105A $1400	G105A $1400	SLOTTED SECTIONS Fixed W.C.
Y115A			TYPE Z116A CARRIAGE		$160			Interchangeable W.C.
			Q151A $110	M151A $100	E151A $190			ATTENUATORS Flap
Y155A $ 90	K155A $135	U155A $170						Semiprecision
						F163A $975	G163A $975	Precision Calibrated
Y164A $275	K164A $425	U164A $450	Q164A $825	M164A $800	E164A $1200			Precision Direct Reading
								Fixed
Y175A $115	K175A $240	U175A $250	Q175A $475	M175A $425	E175A $675	(Values to 30DB)		Fixed Precision
								40DB Step
Y157A $220	K157A $240							FERRITE ISOLATORS
Y205B $175	K205B $175	U205B $200 U206B $200	Q206B $210	M208A $325 M206B $210	E208A $400 E206C $350	F208A $400	G208A $400	CRYSTAL DETECTOR MOUNTS Tuneable
Y212A $ 80	K212A $ 80	U212A $ 80						Fixed
								MATCHED BOLOMETER MOUNTS
Y216A $110	K216A $150	U216S $270						THERMISTOR MOUNTS
Y218A $210	K218A $250	U218S $400						THERMISTOR HEADS TEMPERATURE COMPENSATED
Y311A $130				M311A $195				TUNERS Slide screw
Y312C $135	K312C $155	U312B $170	Q312B $235	M312C $245	E312C $390	F313A $775	G313A $775	E/H
						F314A $950	G314A $950	PRECISION PHASE SHIFTERS
								DIRECT READING FREQUENCY METERS Precision
Y410A $210	K410A $230	U410A $250						Reaction
			Q410X $325	M410X $300	E410X $500	F412A $750	G412A $750 G413A $800	Reaction, micrometer
								Transmission
Y501A $ 24	K501A $ 30	U501A $ 35	Q501A $ 95	M501A $ 90	E501A $150	F501A $150	G501A $150	TERMINATIONS Fixed
Y502A $ 50	K502A $ 70	U502A $ 75						Sliding
								High power
Y510A $450	K510A $480	U510A $625						STANDARD MISMATCHES VSWR 1.00
Y510B $325	K510B $340	U510B $525						VSWR 1.05
Y510C $275	K510C $280	U510C $450						VSWR 1.10
Y510D $225	K510D $240	U510D $280						VSWR 1.20
Y510E $325	K510E $340	U510E $350						VSWR 1.50
								WAVEGUIDE-TO-COAX ADAPTERS
Y610A-D $100 Models A-3DB, B-6DB, C-10DB, D-20DB	K610A-D $165	U610A-D $185		M610A-D $500				DIRECTIONAL COUPLERS Multihole
Y612D $ 55	K612D $110				Models D-20DB, E-25DB			Crossguide
Y620A $ 40	K620A $ 45	U620A $ 55	Q620A $ 65	M620A $ 60	E620A $110	F620A $275	G620A $275	WAVEGUIDE TEES Series
Y621A $ 40	K621A $ 45	U621A $ 55	Q621A $ 65	M621A $ 60	E621A $110	F621A $275	G621A $275	Shunt
Y622A $ 54	K622A $ 65	U622A $ 80	Q622A $100	M622A $100	E622A $170	F622A $325	G622A $325	Hybrid
Y623B $ 32 Y624B $ 32	K623B $ 38 K624B $ 38	U623B $ 42 U624B $ 42	Q623B $ 55 Q624B $ 55	M623B $ 50 M624B $ 50	E623B $ 90 E624B $ 90	F623A $275 F624A $275	G623A $275 G624A $275	WAVEGUIDE BENDS 90° E-plane 90° H-plane
Y625A $ 60	K625A $ 60	U625A $ 70	Q625A $100	M625A $100	E625A $100	F625A $100	G625A $100	WAVEGUIDE 90° TWISTS
Y630C $145	K630C $155	U630B $150	Q630B $155	M630C $160	E630B $250	F631A $275	G631A $275	PRECISION SLIDING SHORTS
Y634A $ 35	K634A $ 38	U634A $ 38	Q634A $ 50	M634A $ 50	E634A $ 50	F634A $ 85	G634A $ 85	STRAIGHT WAVEGUIDE SECTIONS (Min. length)
Y638A $125	K638A $150	U638A $175	Q638A $120	M638A $125	E638A $250	F638A $200	G638A $200	STANDARD GAIN HORNS
Y641A $250 Y641AE $275	K641A $275 K641AE $300	U641A $300 U641AE $325						WAVEGUIDE SWITCHES
								SHIELDED TUBE MOUNTS
			Q780A $165	M780A $160	E780A $250	F781A $475	G781A $475	HARMONIC GENERATORS
Z910B $ 7	Z910B $ 7	Z910B $ 7	Z910C $ 7	Z910C $ 7	Z910C $ 7			WAVEGUIDE STANDS



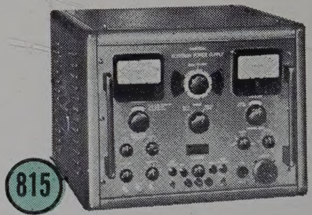
SIGNAL SOURCES

- 950 to 2000 MC.
  Model L772A $1340
- 1900 to 4000 MC.
  Model S772A $1340
- 3950 to 8200 MC.
  Model C772A $1340
- 7000 to 11000 MC.
  Model X772A $1340

TEMPERATURE COMPENSATED POWER METER

- Power Range, full scale —20DBM or 0.010 MW. to + 5DBM or 3.00 MW.
- Type 218 Heads required

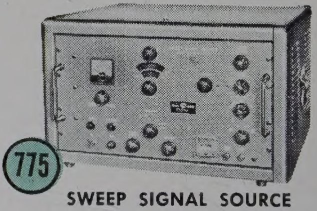
Model B831A • $335
Model B832T (Transistorized) • $450



UNIVERSAL KLYSTRON POWER SUPPLY

- Beam: 200-3600V
  Grid: 0 to +150V; 0 to —300V
  Reflector: 0-1000V

Model Z815B • $1350



SWEEP SIGNAL SOURCE

- Freq. Range: 8200-12400 MC.
- Provisions for AGC

Model X775A • $2900

UNIVERSAL MICROWAVE POWER SUPPLY

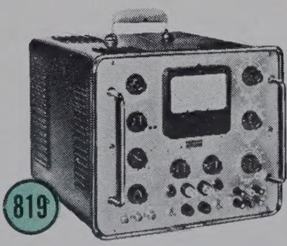
- Helix: 0-3500V
- Filament: 0-15V D.C.
- Separate Grid Voltages #1, #2, #3, #4 plus Collector and Anode Voltages

Model Z817A • $2650

STANDING WAVE AMPLIFIER

- Full scale sensitivity, 0.1μV signal-to-noise ratio 3:1
- Tunable 1000 cps filter

Model B812A • $225

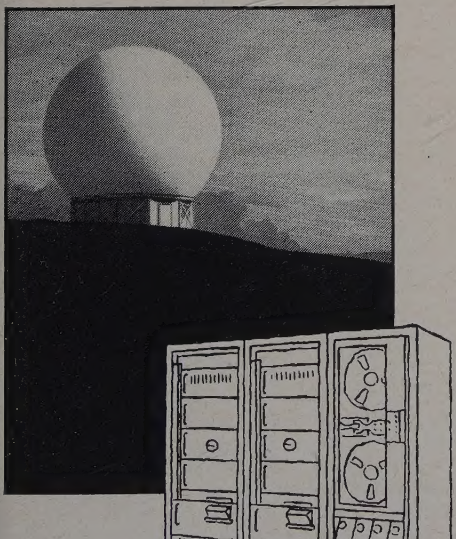


KLYSTRON POWER SUPPLY

- Beam: 300-1000V at 85 MA.
- Grid: 0 to +150V; 0 to —300V
- Reflector: 0-900V

Model Z819A • $625

AT NEW FRONTIERS...



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the microwave journal

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Linear, Complex-Reflection Coefficient Bridge

Centrifugal Forming of Paraboloidal Antennas

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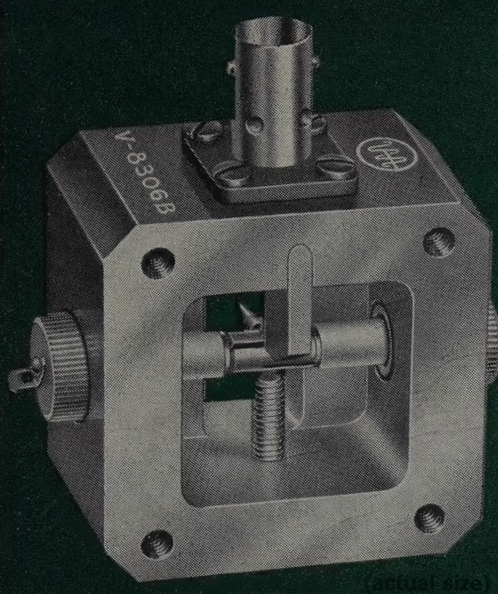
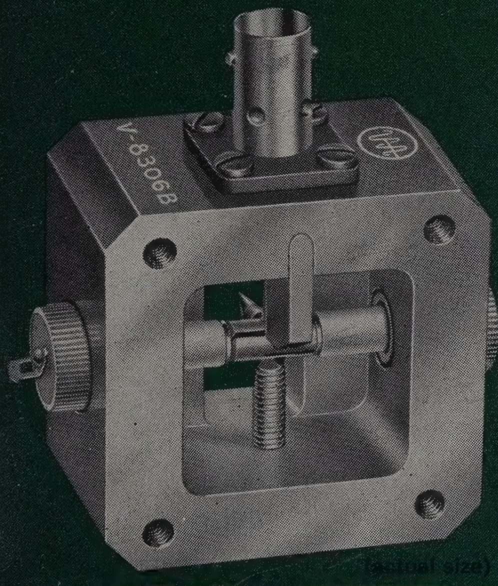
BPA



MIXER



MODULATOR

V-8306B

Carrier Frequency, 7.6-8.6 kMc
Carrier Power, 300 mW max.
Modulating Signal Frequency, 0-100 Mc/s
Carrier Rejection, 20 db minimum
Conversion Efficiency, 8 db nominal

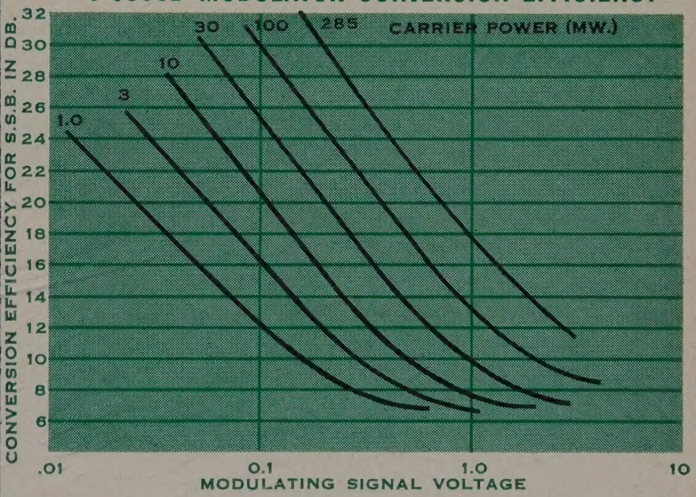
THE MIXER WITH THE DUAL PERSONALITY

Here's important design news! Varian Orthomode® balanced mixers are equally effective as modulators.

When any of Varian's broad line of mixers is operated as a modulator—with microwave power applied to a waveguide port and modulating signal voltage to the IF connector—conversion loss approaches the minimum theoretical level.

Varian mixer-modulators are more compact than TWT's, more efficient than ferrite devices at high modulating signal frequencies. Unusually small size and weight provide the answer to difficult packaging problems. Inexpensive. Designed for straight-line hookup, simplifying waveguide arrangements. Available in X, S, and C bands.

V-8306B MODULATOR CONVERSION EFFICIENCY



For technical data on this exciting new use for Orthomode Balanced Mixers, write Radiation Division.

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NEW HIGH-POWER TRAVELING

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MODEL 491C
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hp 491C High-Power Traveling-Wave Tube Amplifier

The new hp 489A (1 to 2 GC) and 491C (2 to 4 GC) are broad band, low noise Traveling-Wave Tube Amplifiers providing at least 1 watt output for 1 milliwatt input over their full frequency range.

These compact, rugged, dependable instruments are supplied in the new hp universal module cabinet combining, in one single instrument, a lightweight, portable bench amplifier and a neat, clean rack mounted unit.

Both Models 489A and 491C incorporate new, permanent-magnet TWTs, offering low power consumption and solving the heat problem of previous TWT amplifiers. Specially designed circuitry provides amplitude modulation from dc to 100 KC, with internal amplification so that small modulation signals cause a large output power change.

Besides allowing amplification with small input signals, the modulation circuitry can provide leveled power output by using external elements completing a feedback loop.

SPECIFICATIONS

Model:	**489A**	**491C**
Frequency Range:	1 - 2 GC	2 - 4 GC
Price:	$1,970.00	$1,970.00

Common Specifications

Output for 1 mw Input:	At least 1 watt
Maximum rf Input:	100 mw
Small Signal Gain:	Greater than 30 db
Amplitude Modulation Passband:	DC to 100 KC
Modulation Sensitivity:	Approx. 20 db rf change for a 20 v peak mod. sig.
Input Impedance:	50 ohms, SWR less than 2.5
Output Impedance:	50 ohms, SWR less than 2.5
Connectors:	Type N, female
Front Panel Controls:	Gain
Meter Monitors:	Anode, helix, collector and cathode current
Dimensions:	16¾″ x 5½″ x 18⅜″ deep (cabinet convertible to rack mount) 19″ x 5¼″ x 16⅛″ deep behind panel (rack mount)

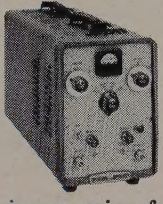
-WAVE TUBE AMPLIFIERS

1 mw INPUT!

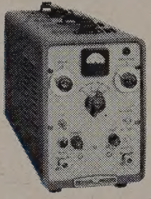
OR MEET YOUR REQUIREMENTS WITH ONE OF THESE BENCH-PROVEN hp TWT AMPLIFIERS

hp Models 490B, 491A, 492A and 494A TWT Amplifiers use a simple broad-band coupling method employing input and output coupling helices. Full energy transfer is effected, even though there is no mechanical connection to the inner helix. A similar helix is used for a coupled attenuator which surrounds the central portion of the tube, preventing amplified energy from causing regeneration. Encapsulated replacement tubes including integral coupling helices are available and are delivered factory-tested and ready to install.

hp 490B TWT Amplifier, 2 to 4 GC, provides at least 10 mw output, 30 db gain with noise figure of less than 25 db, excellent pulse modulation characteristics and helix modulation.



hp 491A TWT Amplifier, 2 to 4 GC, has a full range output of 1 watt, with minimum gain of 30 db. Combined with a 1 mw S-Band signal generator such as hp 616A it provides a versatile full watt source for high power testing.



hp 492A, 4 to 8 GC, and hp 494A, 7 to 12.4 GC, are 30 db gain TWT amplifiers providing 20 mw output. Offering amplitude, pulse, phase or FM modulation, they are ideal for use as broadband amplifiers or isolating buffer stages.

	hp 490B	hp 491A	hp 492A	hp 494A
Frequency Range:	2 to 4 GC	2 to 4 GC	4 to 8 GC	7 to 12.4 GC
Gain:	30 db min.	30 db min.	30 db min.	30 db min.
Output Power:	10 mw min. into 50 ohm load	1 watt min. into 50 ohm load	20 mw min. into 50 ohm load	20 mw min. into 50 ohm load
Noise Figure:	Less than 25 db	Less than 30 db	Less than 30 db	Less than 30 db
Pulse Rise & Decay Time:	Approx. 0.015 μsec.	Mod. not provided	Approx. 0.015 μsec	Approx. 0.015 μsec.
Input Impedance:	50 ohms, SWR less than 2	50 ohms, SWR less than 2	50 ohms, SWR less than 2	50 ohms, SWR less than 2
Output Internal Impedance:	50 ohms, SWR less than 3	50 ohms, SWR less than 3	50 ohms, SWR less than 3	50 ohms, SWR less than 3
Price (including tube):	$1,400.00	$1,400.00	$1,500.00	$1,800.00

Data subject to change without notice. Prices f. o. b. factory.

Call your hp representative today for full information on these versatile TWT Amplifiers.

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MICROVIEWS

OF THE MONTH

77 ▶ CHARACTERISTICS AND APPLICATIONS OF MICROWAVE SPARK OSCILLATORS

Tadasu Kawano

Investigations on the recurrence frequency and the energy of a microwave packet radiating from a spark oscillator are conducted with a single time sweep oscillograph and a microwave power meter. The higher as well as the fundamental mode resonant frequencies of a waveguide filter are measured by the method of the Fourier transform of the standing-wave curve. The VSWR's of waveguide elements measured by spark waves are in close agreement with those measured by single frequency waves. A two receiver coherent detection method is recommended where spark waves are used as wave sources for measurements. Waveguide pulse tests using spark waves are performed without a pulse modulator down to a wavelength of one centimeter.

84 ▶ COMPENSATED ELECTROMAGNETIC HORNS

James J. Epis

An aperture modification or compensation technique for conical and square-pyramidal electromagnetic horns is described in this paper. The modification improves radiation characteristics by producing nearly similar E- and H-plane patterns and, consequently, a nearly circularly symmetric radiation polar diagram. Important features are that the polar diagram compensation is effective for a broadband, and is equally effective for every possible linear, circular, and elliptical polarization. Typical E- and H-plane radiation patterns and the input VSWR of conical horns measured before and after the aperture modification are presented for comparison.

92 ▶ DESIGN CHART FOR QUARTER-WAVE STUBS

Leo Young

Quarter-wave stubs are commonly used in coaxial and strip transmission lines. They can be designed to have low VSWR over very wide frequency bands. The design data for ideal junctions has been reduced to a single convenient chart.

93 ▶ THERMAL NOISE IN MICROWAVE SYSTEMS — PART III

A. E. Siegman

This final section of the series of articles on noise considers first some of the practical problems which arise when one attempts to (a) achieve an ultra-low-noise amplifier; (b) make good use of it in a system; and (c) measure its noise performance. The problems are illustrated by discussion of a maser amplifier system. In the concluding sections, the question is asked: is there an ultimate lower limit to the noise figure of an amplifier? The answer is found to be yes. The concept of quantum counters is discussed, and their relation to the ultimate noise limit is pointed out.

OUR COVER

Shown is a model of a conical horn used as a feed antenna in an S-band, automatic tracking antenna of new design. The pins on the periphery of the conical horn modify its radiation pattern in a manner which improves the error signal characteristics of the tracking antenna. The operation of similar "compensated" electromagnetic horns is described on page 84.

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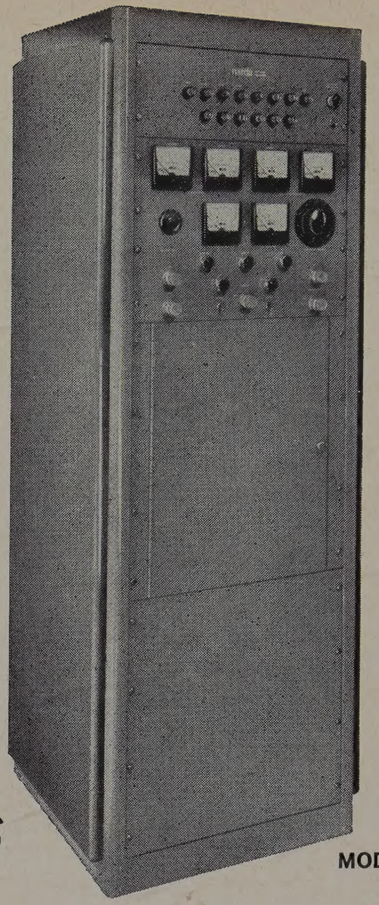
For greater versatility... longer life... increased reliability...

Specify NARDA Microwave Modulators



MODEL 10002
35 KV

ere's a line of new Microwave Modulators, designed to operate maximum number of existing magnetrons, without any alterations) the modulator. In addition, provision has also been made for uickly converting the unit to handle any new or uncommon pulse iicrowave tubes.

Models 10001 and 10002 are designed to handle high-power iagnetrons with provision for internal mounting of the tube. Model 0003 is designed for pulsing low-power magnetrons of the type now sed in beacon transmitters and for low-power commercial pulse pplications.

Since all units utilize silicon rectifiers and diodes, you can expect increased life and more reliable operation. At the same time, over-all size has been considerably reduced. Every Narda Microwave Modulator is complete with built-in safety provisions, built-in meters and viewing connectors for all principal parameters, a continuously variable repetition rate, and a standard pulse width of 1 microsecond (other widths available on special order) on Models 10001 and 10002; continuously variable on Model 10003.

The specifications below indicate those characteristics of the three new models which vary from each other. The listing of features indicates those features common to all models. For additional information, and a copy of our free catalog, write to us at Dept. MJ-9.

SPECIFICATIONS

Narda Model #	Maximum Peak Pulse Power	Pulse Width (Microseconds)	Maximum Duty Cycle # at Maximum Power	Size H x W x D
10001	18KV@20A	1*	0.001	38x22x18
10002	35KV@40A	1*	0.001	67x24x24
10003	4.5KV@2A	0.5-2.2†	0.002	8½x18x12

* Other values of pulse width can be readily substituted.
† Pulse width is continuously adjustable over given range.
# Internal continuously variable trigger generator for adjusting repetition rate and duty cycle.

FEATURES

Built-in Meters:
- High voltage power supply voltage
- High voltage power supply current
- Magnetron filament supply voltage
- Magnetron filament supply current
- Clipper average supply current*

*Models 10001 and 10002

Viewing Connectors (BNC):
- Magnetron pulse voltage
- Magnetron pulse current
- Primary pulse voltage*
- Thyratron pulse current*
- PFN charging voltage*

*Models 10001 and 10002

Output sync pulses (BNC Connectors):

Positive
+ 50 v min. at 2 sec.
Negative
— 25 v min. at 2 sec.

Input sync (BNC Connectors):

Sine wave:
20 v RMS min.
Pulse:
20 v at .25 sec min.

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HIGH POWER ELECTRONICS DIVISION
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THE TIME SHORTAGE

One of the great shortages that doesn't get enough attention is the shortage of time. By this I do not mean to imply that we should work towards a sixty hour week or a twelve hour day.

What concerns me is the amount of valuable time wasted each day by literally thousands of our top technical people. The areas of waste are many and vast.

Each of us can think of a variety of waste situations, but I would like to confine my comments to just two areas of interest.

The first is the problem of pre-contract negotiation. How many times have contract negotiations gone on for months, even years, prior to the placing of an order? The resultant order, on the other hand, must be delivered in a fraction of the time devoted to the original negotiations. True, some of the time devoted to negotiation is important and fruitful, but how much? What is even more significant is that the people involved in the negotiations are usually top administrative and engineering personnel.

It is not uncommon for a company to devote at least five times the elapsed time on negotiations as compared to the time devoted to the completion of the contract itself.

We've all been exposed to it or have exposed others to it. More and more we are finding that after six months to a year of pre-contract negotiations, 30 to 60 day delivery is demanded.

Even in professional basketball there is a 24 second rule during which time an attempt must be made to score a basket, or possession of the ball is forfeited.

The other area of waste is the business of quoting. It is not out of the ordinary for as many as ten companies to quote on the same item. A good quote can involve anywhere from 5 to 15 per cent of the total time involved in the final program. What it amounts to in many cases is that as much prime engineering time is involved in quoting a contract as is spent on prosecuting the contract itself.

Of course, the one requesting the multiple quotes is not perturbed, since it costs him practically nothing. It is also true that a few programs should involve many quotes.

It can be, and has been, argued that these facts are a necessary evil of our Democratic process. That is a poor reason to accept the conditions without protest.

In the interest of saving valuable time, some attention should be given to these matters.

Ted Saad

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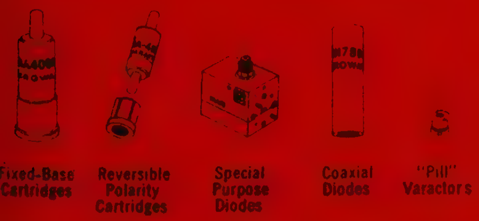

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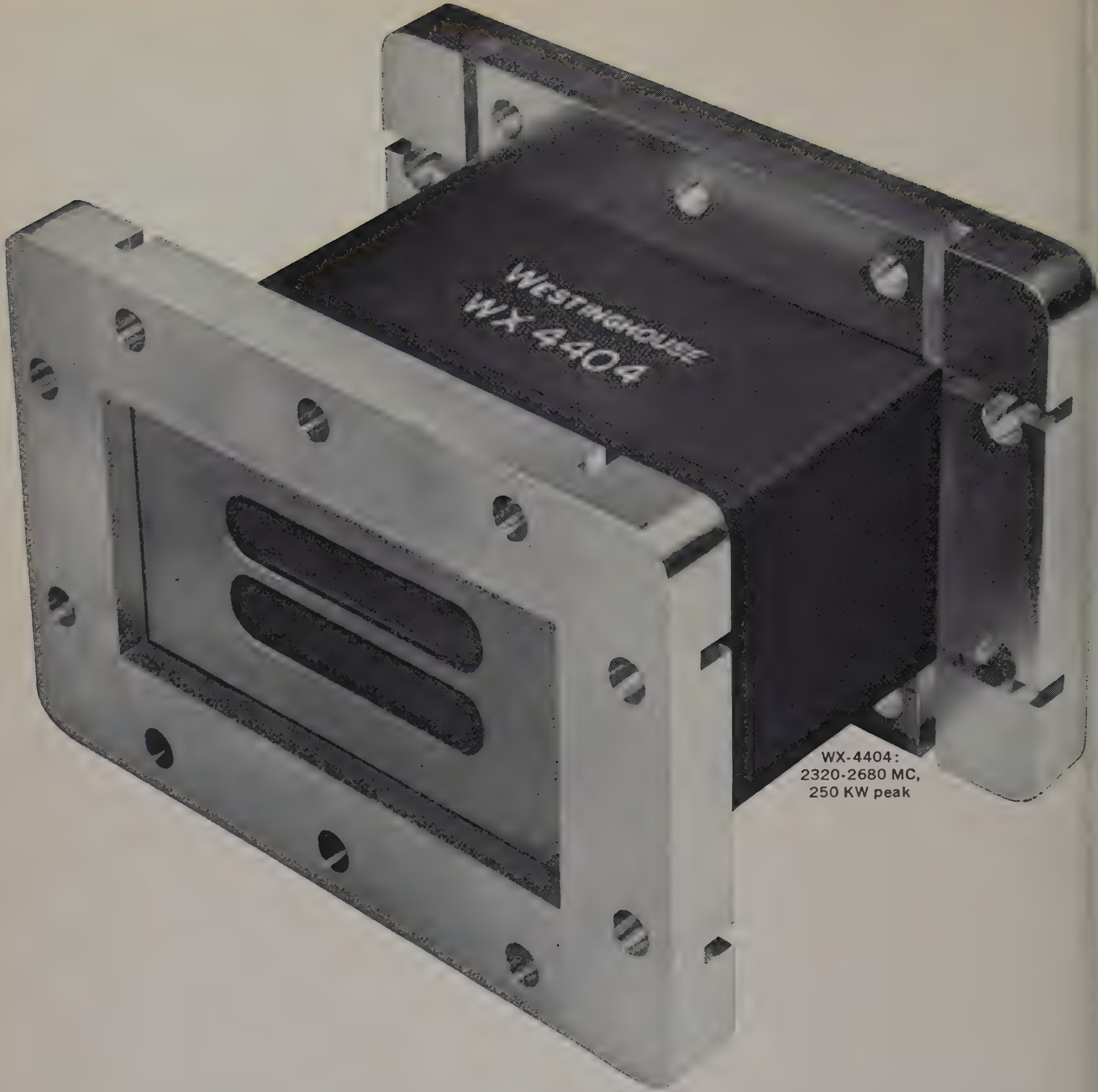

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2320-2680 MC,
250 KW peak

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Westinghouse

Circle Reader Service Card 5

Dr. Daniel GOODMAN

Manager

MICROWAVE COMPONENTS LABORATORY

SYLVANIA ELECTRIC PRODUCTS, INC.
Mountain View, California

By ADELAIDE PAINE

The words of Ralph Waldo Emerson, "Whoso would be a man must be a non-conformist," might well be the motto for Dr. Daniel Goodman. This unassuming, soft-spoken man, quiet in dress and manner, believes that one must uphold the dignity of the individual rather than practice "togetherness". He speaks emphatically on the importance of the non-conformists in our society today. He not only speaks in their defense, he acts for them by trying to find such men for his organization.

"I always try to hire someone who knows more in his field than I do," Dr. Goodman said. "I refuse to create an individual in my own image. When I hire someone, I tell him what his job is to be, not how to do it." He does not always find this viewpoint shared by others in management, but he stands firmly behind his principles.

With this for a philosophy, Dr. Goodman, who subscribes to being a non-conformist himself, began work with Sylvania in traveling-wave tube devices, later heading that division. Then he was placed in charge of the research department, soon was head of all engineering including the R & D group, and finally reached his present position as Manager of the Microwave Components Laboratory in early 1960.

Dr. Goodman's experience in the microwave field began as far back as 1947 when he worked with Professor David Sloan of the University of California on high-power microwave sources. They were intent on looking for methods of generating high-average powers at microwave frequencies. Today one of the biggest problems in the microwave field is the search for high-average powers, so that Professor Sloan was ten years ahead in 1947 with research in this area.

At this time, in addition to the work on resnatron tubes, new electron sources such as plasmas, where free electrons were pulled from a metallic arc discharge, were examined. In the latter they succeeded to a degree, and the research in this is still continuing at the University of California. They worked, too, on the study of the phenomena of a metallic arc in vacuums.

During the years 1945 through 1953, while at the University, Dr. Goodman received his BS and his master's degree in high-voltage breakdown and finished his doctoral thesis on "The Density Modulation of an Electron Stream From a Field Emitter Cathode." He said that throughout his college years Professor Sloan was an inspiration to him and the man most responsible for his research in the microwave field.

Since coming with Sylvania in 1953, Dr. Goodman's primary job has been in developing a line of traveling-wave tubes which were part of the major effort in building the B-58 Passive Defense System. Now as Manager of the Components Lab, he has the responsibility for the Research and Development activities for the Microwave Device Operations of Sylvania which include traveling-wave tubes, klystrons, cross-field devices, ferrite devices and gas-switching devices.

Knowing that he came from a completely unscientific background (his father was a wholesale grocer) I asked Dr. Goodman what had originally led him into engineering. "I played with radios even as a boy," Dr. Goodman answered. "But my childhood was spent during depression years and there was little money for unessentials such as radio. My father barely hung on to his business in those days."

Though raised in Texas, he considers himself "from" Texas, not "of" Texas. "That weather!" was another way he had of expressing his desertion of Texas for California.

He received some intensive training in radio and radar during the war, having entered the service in 1940 and

(*Continued on page 14*)

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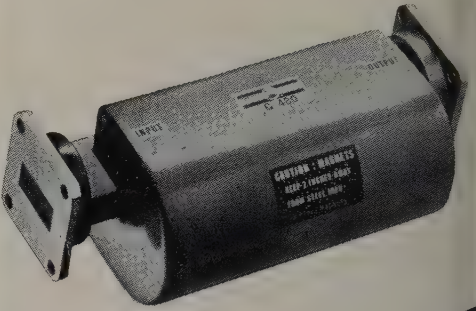

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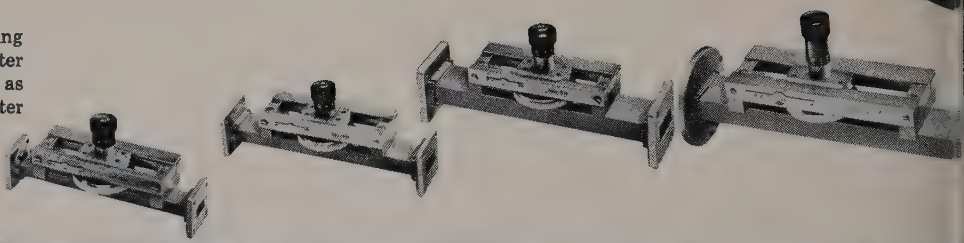

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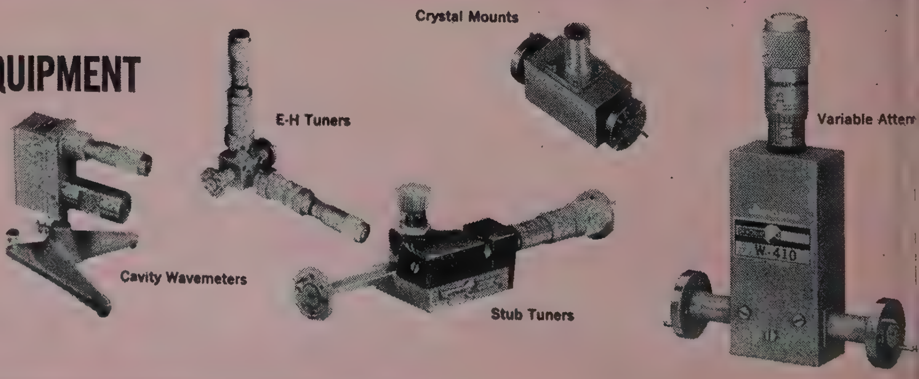

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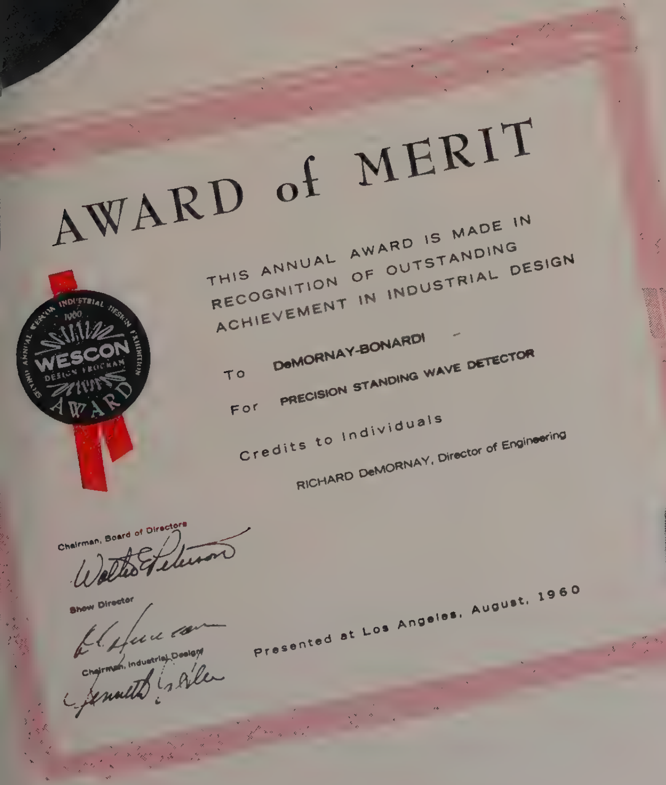

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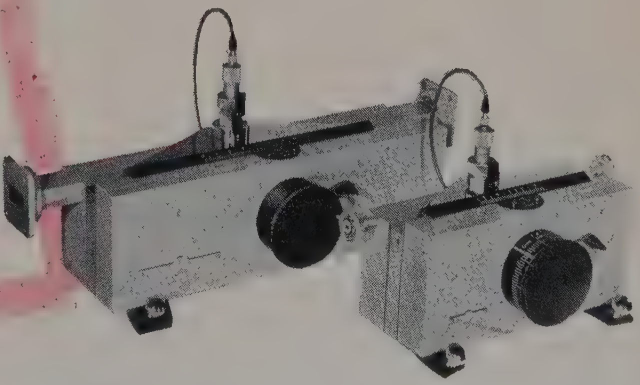

GOODMAN

(Continued from page 11)

serving for five years in the radio field before he was discharged. He was sent to the Naval Radio School at Indianapolis and the Naval Research Laboratory in Washington, D.C. Of his naval career, he says, "I spent two-and-a-half years counting coconut trees." Actually, most of the time he was aboard a battleforce repair ship in the South Pacific.

When asked if there was an outstanding moment during his war years, he chuckled. "Just the other evening I was reminiscing with friends about the war," he said. "And I think that the most memorable part of the war for me was the night I was landed with an Advance Repair Unit on New Caledonia.

"We were landed with the bare essentials on a dark night and quickly pitched our tents, put up our cots and fell in. All night I kept slipping feet first out of bed and slept fitfully.

"Finally I got up at dawn and went outside, somewhat the worse for wear. I took one surprised look around the beach and burst out laughing. My laughter woke up the rest of the group who all filtered out wanting to know what was up. I just pointed, and they collapsed with laughter. Soon all 150 men were on the beach in hysterics.

Dr. Goodman compares new traveling-wave tube with the older larger type.

"The rising sun showed that we'd pitched all our tents on a hillside and they were perpendicular to the hill and at an angle of about 20 degrees to the horizon. Everyone else had had my problem of trying to sleep standing up in bed."

During the war, Dr. Goodman married his wife Helena, a fellow Texan. Though she worked for several years, she gave up her outside job when the bigger one of raising a family came along. They have two children. As Dr. Goodman says, "I have a girl and a character." The character is an energetic boy of six named Kennard. The girl Leslie at twelve is in the eighth grade and has always been mature for her age according to Dr. Goodman.

"My wife, outside of managing the household, keeps her finger in the PTA pie," he commented. He, himself has taken quite a strong interest in education and recently served on the Mathematics Curricula Committee of the Palo Alto School System to review the math program and make recommendations.

He does not believe that the matter of accelerating the bright children is as much of a problem as doing something about accelerating the teaching methods, the teaching time. "In the last 75 years we have shortened the time required to cross the United States from five months to five hours, but we have done nothing about shortening the time required to complete school." With the accelerated pace of the world, he feels that our children are ready for earlier and more thorough education. "Even the so-called 'average' child, and I want quotes around average, is often bored at school and is capable of absorbing more material than he is given."

The American dream of a college education for all is not realistic, he feels. Children not suited to college should be trained early as technicians or skilled mechanics. The present system, he believes, does not make either good college students nor good technicians.

But, as he says, "If you added up all my pet peeves on what is wrong with education, I would lay the blame on the reluctance of the taxpayer. Without adequate salaries how can we hope to attract and keep the best people in teaching."

He takes violent opposition to such words as average, normal, teenager—any word that attempts to categorize individuals into groups. "There are certain social mores we must abide by," he said, "but we must learn to think for ourselves, act for ourselves. Being non-conformis does not mean being oddball." He believes people spend too much time doing what is expected of them and no having time to do the things they want to do or should be doing.

Not always following the crowd is something he stresses to his children. Though Dr. Goodman says when he's ready to criticize his children for conforming, he tries to remember his own youth when a boy wasn't accepted in high school unless he wore dirty cords.

Even the Goodman house is non-conformist. In an area where shake-roofed ranch houses overpopulate the landscape, his new modern house is a soaring glass and frame structure on a hillside. He likes to build a new house every five years as the family wants and interests change, each house being a challenge to him.

When asked if he made mistakes in building his present home, he nodded. "You must have a philosophy about uilding houses or you couldn't continue. Ours is that if house has no more than 25 major and 50 minor mis-kes, we've done a good job.

"My hobby is cabinet making," he said proudly. "I build urniture, cabinets, anything in wood. The new house as constructed around my workshop which has 500 quare feet of work area. In fact," he admitted, "we really uilt the new house just so I could have a workshop. No ore of this business of having to leave the car outside nd keeping the garage full of sawdust."

I asked him if fine woods weren't difficult to discover. e agreed, adding that they were quite costly, too. "It n't necessarily less expensive to build your own furni-ure, it's just that I enjoy working with woods. I've been oing it now for over thirty years."

When I asked if the furniture he made was modern, e said, "No. I say that because there is no such thing as odern furniture. There is functional or unfunctional urniture. Mine is the former. Some people might ll my dining-room table modern because it is simple, unctional."

Asked if he had any special committees or projects he as working on outside the office, he said that he has ttle time for work on professional committees anymore, hough he once chaired the San Francisco Chapter of .G.E.D.

When I explained that I had not realized at first that e had a doctorate, he said that he deliberately didn't use he title. "I am not very impressed with my own title. I find this also to be true with most of my associates with a PhD. However, I do not underestimate the effort that has gone into getting a doctorate and I feel this is not too well recognized."

His wit was most in evidence when he added, "Actually, I find the title 'Doctor' most invaluable when I want to get a reservation at a restaurant. The title helps me obtain a better table. And I want you to quote me on that."

His non-conformist attitude is just as often present in the conference room. "I believe in having people look at all sides of a question before making a decision," he said. "I take the opposite side just to stimulate thought. Or if a man is arguing his side well and I'm opposing him, I often say, 'Now you take my position and I'll argue yours.' "

In inquiring whether he missed his closer contact with engineering now that he is a Manager, he replied, "I'm in the position I wanted to reach, but I find there is less engineering than I thought there would be. My biggest frustration is not being able to be as close to as many of the projects as I would like to be. Still, I find the job most challenging."

Dr. Goodman obviously practices what he preaches. He is a non-conformist, unashamed. A man large of stature, large in scope of ideas, yet with time to look at the smaller aspects of life on our planet. There seems little chance he will ever find life anything less than challenging, nor will his associates.

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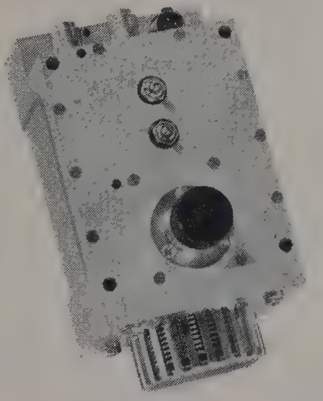

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P-30	Power amplifier	16	2.5w	10	25w	15	600v @ .090a
X2-30	Frequency doubler	—	—	2.5	3w	8	300v @ .050a
X3-30	Frequency tripler	—	—	—1	2w	7	300v @ .050a
P-31	Power amplifier	N/A	N/A	10	50w**	15	1000v @ .090a

Heater is 6.3 v @ 1a for all units.
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Here are a few specifications on the Modes 344M Pulse Modulator:

· Peak power output	1.2 megawatts
· Peak pulse voltage and current	0-40kv, 0-30a to 5,000 pps 0-30kv, 0-30a to 10,000 pps
· Pulse width (90%)	0.1-5.0μsec continuously variable
· Maximum duty cycle	.002

For technical and performance data, write Radiation a Stanford, 3180 Hanover Street, Palo Alto, Calif.

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Mode Filter	A340	V340	E340	F340	VSWR 1.2 — Loss: TE$_{01}$ mode .3db, TE$_{11}$ mode 10db	Helical waveguide surrounded with lossy material
Rotary Joint	A350	V350	E350	F350	VSWR 1.1 — Loss .3db — WOW .1db — Phase Variation 2 degrees	TE$_{01}$ circular waveguide — high speed rotary joint also available
90° Bend	A360	V360	E360	F360	VSWR 1.15 — Loss — .3db	Corrugated circular waveguide — TE$_{01}$ mode
Flanged Straight Lengths	A370	V370	E370	F370	Inside Diameters: A — 643", V — 353", E — [illegible]", F — 18[illegible]"	Priced up to 24" long — longer sections quoted on request

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NEW BELL LABORATORIES RESEARCH FORESHADOWS COMMUNICATIONS AT OPTICAL FREQUENCIES

A revolutionary new device, the continuously operating Optical Gas Maser, now under investigation at Bell Telephone Laboratories, foreshadows a whole new medium for communications: light.

Light waves vibrate at frequencies tens of millions of times higher than broadcast radio waves. Because of these high frequencies, a beam of light has exciting potentialities for handling enormous amounts of information.

Now for the first time, Bell Laboratories' new Optical Gas Maser continuously generates light waves that are "coherent." That is, the light waves move in phase as seen looking across the beam.

With further research, it is expected that such beams can be made to carry large amounts of information. The beams can be transmitted through long pipes. They can be projected very precisely through space, and might be used for communications between space vehicles.

Research with coherent light is another example of how Bell Laboratories prepares ahead for communications needs.

The Optical Gas Maser (above) was first demonstrated at Bell Telephone Laboratories. Heart of unit is a 40-inch tube containing helium and neon. Interaction between gas atoms produces a continuous, coherent beam of infrared light that may one day be used in communications.

BELL TELEPHONE LABORATORIES
WORLD CENTER OF COMMUNICATIONS RESEARCH AND DEVELOPMENT

Industry News

SANBORN, HEWLETT-PACKARD DISCUSS COMBINATION

James L. Jenks, Jr., Chairman of the Board of Directors of Sanborn Company, Waltham, Massachusetts, and David Packard, President of Hewlett-Packard Company, Palo Alto, Calif., have announced that the managements of their respective companies have tentatively agreed upon a basis of combination of the two companies for submission to the boards of directors and stockholders of each company.

Under the proposed combination, stockholders of the Sanborn Company would receive for each share of Sanborn stock 1.4 shares of common stock and 1 share of cumulative convertible preferred stock of Hewlett-Packard Company. The preferred stock would be a new issue of no-par stock carrying an annual dividend rate of $.90 per share, callable after four years at $18.00 per share and convertible at any time into 0.4 shares of common stock of Hewlett-Packard Company.

The consummation of the combination will be subject to preparation of a mutually acceptable formal agreement covering details, the requisite approval of the boards of directors and stockholders, and the listing upon the New York stock exchange of the additional shares of Hewlett-Packard Co. common stock. The Messrs. Jenks and Packard stated that the business of the Sanborn Company would be continued as a separate corporation under its present name retaining present personnel, management and policies.

— *m w j* —

DERBY NAMED MARKETING MANAGER

Palmer Derby has been named marketing manager for the Microwave and Power Tube Division of Raytheon Co., Waltham, Mass. He succeeds George C. Trotter who has been appointed to the newly created corporate post of consultant, microwave components.

Derby was most recently manager of sales programs for the division. He joined the company in 1942 and held various posts in tube design and development. He has been concerned with design and development of more than 800 tubes for military and commercial applications.

In 1952, Derby was appointed head of the magnetron design section of the microwave power tube lab and named manager of the lab in 1954. Upon the opening of Raytheon's Spencer Laboratory at Burlington, Mass. in 1959, he became assistant manager of that facility.

Derby attended Virginia Polytechnic Institute and Massachusetts Institute of Technology. He and his family reside at 63 Robin Road, Weston, Mass.

— *m w j* —

ARIZONA CONFERENCE SET FOR NOVEMBER

The Seventh Annual Conference on Magnetism and Magnetic Materials will be held in Phoenix, Ariz., November 13-16, at the Hotel Westward Ho. This conference is sponsored jointly by the American Institute of Electrical Engineers and the American Institute of Physics, in cooperation with the Office of Naval Research, and the Metallurgical Society of the A.I.M.E.

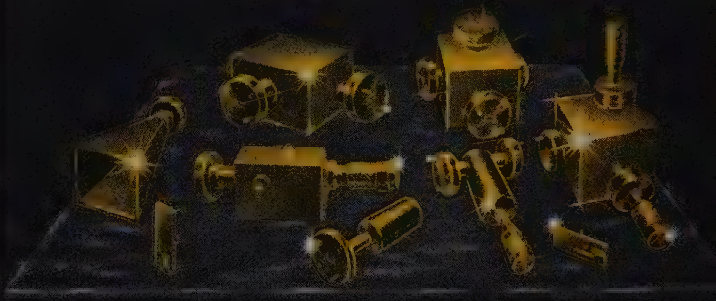
The deadline for abstracts is August 18. Further details can be obtained from the local chairman, Peter B. Myers, Motorola Semiconductor Products Division, 5005 E. McDowell Road, Phoenix, Arizona.

— *m w j* —

(*Continued on page 20*)

Circle Reader Service Card 15 ➧

These Millimeter Waveguide Gems Are A Microwave Man's Best Friend



"A diamond is forever" but these precision gems are specifically engineered to meet the ultra-high frequency requirements of an ever-changing industry. Whatever your field . . . communications equipment, spectroscopy, feasibility testing or radar operations . . . if microwave is your meat, these WR 5 Millimeter Waveguide Components will provide the precious element of precision to make any G-band system sparkle. They feature electroformed waveguides with gold plated internal walls, true rectangular guides and high precision dimensional tolerances, and conform to RG-135/U (140-220 kMc/s) dimensions. Priced in a range to make them necessities, yet priceless in the precision performance they provide, components in the WR 5 Millimeter line proudly carry the Microwave Dynamics trademark . . . a Symbol of Reliability in the Microwave Field.

Send for detailed data sheets on these components:

• Precision Direct Reading Rotary Vane Attenuator • E/H Tuner • Precision Sliding Short • Standard Gain Horn • Frequency Meter • Fixed Termination • Slotted Line • Flap Attenuator • Detector Mount and Cartridge • Harmonic Generator Mount and Cartridge

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modular design enables you
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Antenna Pattern Recorders — Servo and Electro-Manual Controlled Antenna Mounts — Microwave Receivers — Model Support Towers — Boresight Systems — Position Indicators — Antenna Pattern Integrators — Fork-controlled Oscillators — Anechoic Chambers — Radome Mounts — Source Positioners

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Industry News

(*Continued from page 19*)

SYMPOSIUM DUE ON RADIO FREQUENCY INTERFERENCE

The Third National Symposium on Radio Frequency Interference will be held in Washington, D.C., at the Sheraton Park Hotel on June 12 and 13, 1961. The Chairman of the Symposium is D. R. J. White, Vice President and Director of Research at Frederick Research.

The symposium program will represent a departure from past symposia in that it will make strong use of panels to discuss highly controversial matters. The Symposium emphasis will be placed on the DOD Tri-Service Radio Frequency compatibility program.

—mwj—

ANDERSON ELECTED PRESIDENT OF E.M.T. CORP.

Tore N. Anderson was elected President and Chairman of the Board of the E.M.T. Corp., Syosset, N. Y. at a meeting of the Board of Directors May 1, 1961.

B.M.T. Corporation, which specializes in flexible waveguides for the microwave industry, has been at its new plant in the Syosset Industrial Park since January, 1961, after having acquired Marflex, Inc. a precision machine and tool shop to facilitate production.

Mr. John Lamb, originally chief microwave engineer with Co-operative Industries became Vice President in charge of engineering and Mr. Mark LaMendola became Vice President for Production.

Mr. Anderson is a former President of FXR, Inc. also Vice President and Director of Engineering at Airtron, Inc. Division of Litton Industries for nearly twelve years.

Chairman of the Professional Group on Microwave Theory and Techniques (IRE) and a consultant to the Department of Defense Advisory Group on Electron Parts, Mr. Anderson has been active in waveguide standardization with the E.I.A. and is the U. S. delegate to the International Electrotechnical Commission and secretary of the I.E.C. committee SC 46-A on international Waveguide Standards. He is an Associate Editor of *the microwave journal.*

—mwj—

CURTIS NAMED MANAGER OF RADAR LAB

Charles W. Curtis has been named manager of the radar laboratory at Hughes Aircraft Company's ground systems group, Fullerton, Cal., Dr. Nicholas A. Begovich, assistant group manager, has announced.

Curtis previously was manager of the company's components division. He joined Hughes in 1949.

Curtis received a bachelor of arts degree in physics from the University of California at Berkeley in 1947. He is a member of the Institute of Radio Engineers and the Scientific Research Society of America.

—mwj—

(*Continued on page 22*)

MC μ/φ Channel Filters

FOR ECM APPLICATIONS

The following are the general specifications
of the S-Band Monitor Rack:

Frequency Coverage	2.0 to 4.0 kmc, in 40 plug-in filters
Channel-Filter Performance	
Half-Power Bandwidth	50 mc
Passband Insertion Loss	3 db max
Passband Ripple	1.0 db max
Adjacent-Channel Center-Frequency Isolation	25 db min
Temperature Stability over the Operating Ranges	0.2%
Video Sensitivity	45 to 50 dbm
Environmental Specifications	MIL-E-5400C MIL-T-5422E, Class I except −54 to +85°C.

Many Countermeasures Receivers employ a system of RF filtering to separate a broad frequency spectrum into narrow and discrete bands for the identification and analysis of unknown signals. **Microphase** has developed narrow-band microwave-channel filters specifically designed for ECM applications.

A typical S-Band Filter/Detector Rack is shown here. It consists of ten plug-in channel filters, RF manifold, and video detectors. In addition to the video-output jacks located at the rear of the equipment, each filter has an RF monitor accessible from the front of the panel. With this arrangement, any signal appearing in one of the channels is immediately available for analysis.

Some of the advantages offered by **Microphase** Channel Filters are Reliability — Interchangeability of Channels — Frequency Coverage without Blind Spots — and Savings in Size and Weight.

MICROPHASE
CORPORATION

Box 1166W Greenwich, Conn. NO 1-6200 WE 9-9190 TWX GNWICH CONN 759

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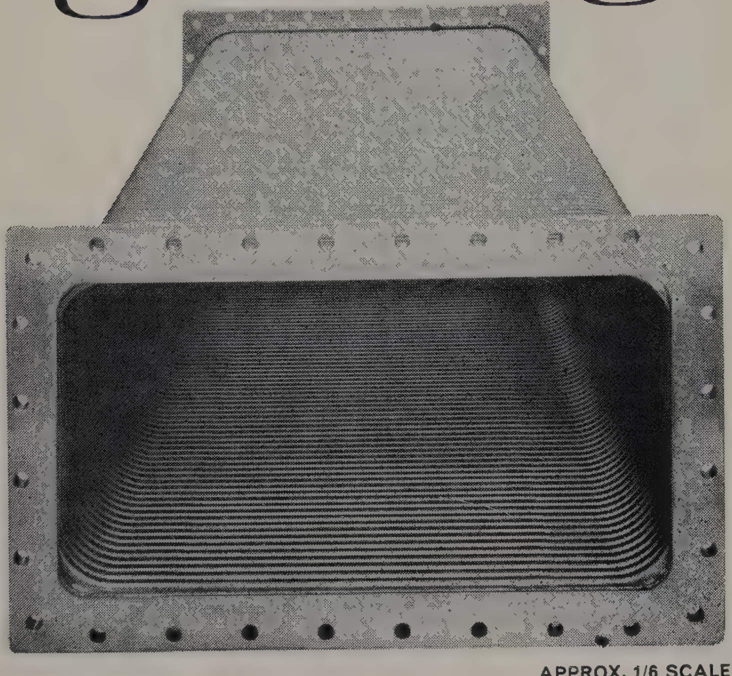
guiding



APPROX. 1/6 SCALE

light

WITH A CROSS SECTION OF 10½ BY 21 INCHES, this is the largest and lightest-weight waveguide ever made. The all-aluminum construction significantly reduces weight, as well as the possibility of corrosion. Other important advantages: high temperature applications up to 700° F.—low VSWR and attenuation characteristics—and the ability to handle extremely high power (designed for several hundred KW of average power and over a hundred megawatts of peak power). Airtron aluminum flexible waveguides are available in a number of sizes from WR-90 to WR-2100. Write for additional facts.

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A DIVISION OF LITTON INDUSTRIES

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Industry News

(*Continued from page 20*)

EIA: EARTH, SATELLITE FREQUENCIES SHOULD BE SHARED

The Electronic Industries Association's Microwave Section reaffirmed to the Federal Communications Commission findings that world communications systems using space satellites can be operated without interfering with existing point-to-point surface radio services.

Radio frequency reservations for surface communications, the EIA section declared, should be amended to permit channels to be shared by satellite systems which will make possible world communication services unattainable prior to the space age.

In a statement filed with the FCC in conjunction with its study of allocation of space communication frequencies, the EIA section also recommended that:

All earth terminals for satellite communication systems be set apart by regulatory definition and that hearings prior to their licensing be made mandatory.

Engineering standards be established applicable to satellite and surface communication systems and that methods be developed for applying the standards in frequency-sharing determinations.

Sharing of frequencies, as opposed to allocation of separate bands for satellite systems, is made necessary by the fact that estimated requirements for space communications for military and commercial purposes are greater than channels available in the usable radio spectrum, the EIA group said. The statement urged that non-government as well as government satellite systems share allocations now reserved for surface systems.

—mwj—

CONFERENCE DUE ON NON-LINEAR MAGNETICS

The Sixth Annual Special Technical Conference on non-linear magnetics will be held at the Statler Hilton Hotel in Los Angeles, Cal., from November 6 through November 8, 1961. This conference is under the auspices of the American Institute of Electrical Engineers and the Institute of Radio Engineers. The theme of the Conference will be "Magnetics in the Space Age".

Dr. T. Bernstein has been named technical program chairman and is soliciting papers dealing with non-linear magnetics, magnetic amplifiers, computer applications, combined semiconductors and non-linear magnetics. Abstracts of less than 200 words should be submitted as soon as possible but are not essential.

Submit all papers or questions to: Dr. T. Bernstein, Space Technology Laboratories, Inc., P.O. Box 95001, Los Angeles 45, California.

Closing date for transaction papers is June 1, 1961. Closing date for Conference papers is August 1, 1961.

—mwj—

(*Continued on page 24*)

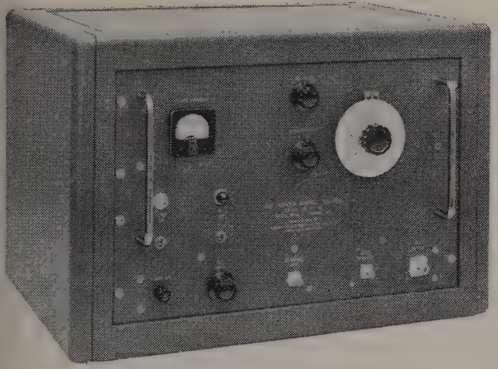
Delivery from stock

NEW VHF-UHF POWER SOURCES

FULL-RANGE STABILITY

50 WATTS OUTPUT

25 to 1,000 MC!



Available in four off-the-shelf models covering the frequency range 25 to 1,000 MC, the new Sierra Electronic Corporation Model 215 Series VHF-UHF Power Sources provide extremely stable output to 50 watts. This unusual stability insures high repeatability for both routine check-out and precision laboratory work.

The instruments are continuously tunable over their respective ranges, offer high frequency stability and dependable operational stability under line voltage variation. Output power is adjustable 20% to 100% of rating. A plate current meter is provided for coupling adjustment, and a front-panel jack permits frequency monitoring with an external counter.

Sierra 215 Series Power Sources are easy to operate, completely self-contained and housed in sturdy bench cabinets. Rack mountable models also are available. They are ideal for accurate calibration of bi-directional power monitors and termination wattmeters, as well as for work in antenna design or other applications involving high attenuation of input signals.

SPECIFICATIONS

Frequency range:	Model 215A-50, 25 to 50 MC Model 215A-150, 50 to 150 MC Model 215A-470, 150 to 470 MC Model 215A-1,000, 470 to 1,000
Power output:	50 watts nominal, 35 watts minimum into 50-ohm load, adjustable 20% to 100% of full power
Output stability:	± 5% after warmup
Frequency stability:	± 0.05% after warmup
Dial accuracy:	± 2% Models 215A-50/150 ± 3% Models 215A-470/1,000
Resetability:	0.1%
Modulation:	External AM
Price:	$3,300.00.

Data subject to change without notice. Price f.o.b. factory

For complete details, see your Sierra Representative or write direct.

Sierra

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Industry News

(*Continued from page 22*)

CASTRIOTA PROMOTED TO MANAGER AT PRD

Dr. L. J. Castriota has been promoted to the position of manager of engineering at PRD Electronics, Inc., Brooklyn, N. Y., it has been announced.

In 1958, Dr. Castriota was awarded his Doctorate from the Polytechnic Institute of Brooklyn. In 1959, he joined PRD where he became involved in all phases of operations with the company especially with the development of military and industrial microwave calibration systems and special test equipment for field and laboratory applications.

Dr. Castriota is a senior member of the IRE, a member of Sigma Xi and of RESA.

—*mwj*—

MILNE NAMED TO PRODUCT PLANNING BY RCA

Douglas D. Milne has been assigned responsibility for product planning and promotion in the Radio Corporation of America's Microwave Department, it has been announced by W. C. Byrne, Jr., Microwave Marketing Manager.

Mr. Milne joined RCA recently after thirteen years with Motorola Communications and Electronics, Inc., as a mobile and microwave sales representative. Previously he was a radio tube applications engineer with National Union Radio Corporation.

He was graduated from the University of Massachusetts with a bachelor of science degree in physics and from the RCA Institutes where he completed a course in communications engineering.

—*mwj*—

FXR SELLS BUDD-STANLEY SUBSIDIARY

FXR, Inc., Woodside, N. Y., a manufacturer of microwave test instruments and associated high frequency equipment, has sold its Budd-Stanley Co., Inc., subsidiary to a private investment group, it has been jointly announced by Henry Feldmann, president of FXR, and Budd Meyers, president of Budd-Stanley.

The buying group was organized by and includes members of the Budd-Stanley management, but no one from FXR. Budd-Stanley, a microwave components manufacturer, founded in 1950, was acquired by FXR last year. Mr. Feldmann said the sale was for cash approximating the original cost to FXR.

FXR recently completed plans to merge with Amphenol-Borg Electronics Corp. Stockholders of both companies will vote on the merger proposal, Budd-Stanley is moving to a new and substantially larger plant in Syosset, Long Island.

—*mwj*—

BRICK HEADS INFORMATION PROCESSING GROUP

The appointment of Dr. Donald Brick as manager of the newly forme information processing group the Applied Research Laborator of Sylvania Electr Products Inc., Wa tham, Mass., ha been announced Dr. Leonard Sheingold, Laboratory Director.

Dr. Brick's grou will be responsib for research in bionics, speech and patter recognition, statistical decision theor artificial intelligence information retriev and related areas in the data and info mation processing fields.

With Sylvania since 1955, Dr. Bric was formerly a research fellow at Harvar University where he worked on electro magnetic scattering, antennas, and microwave circuits. During the past five year Dr. Brick has directed a variety of wor in electromagnetic theory, applied physic countermeasures and counter-countermeasures, missile guidance and radar system Among his more recent projects has bee the study of the use of artificially generated clouds for communication purpose

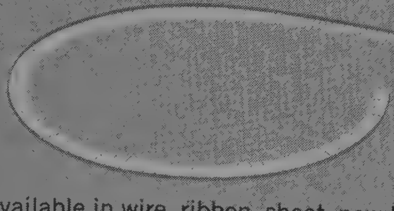
—*mwj*—

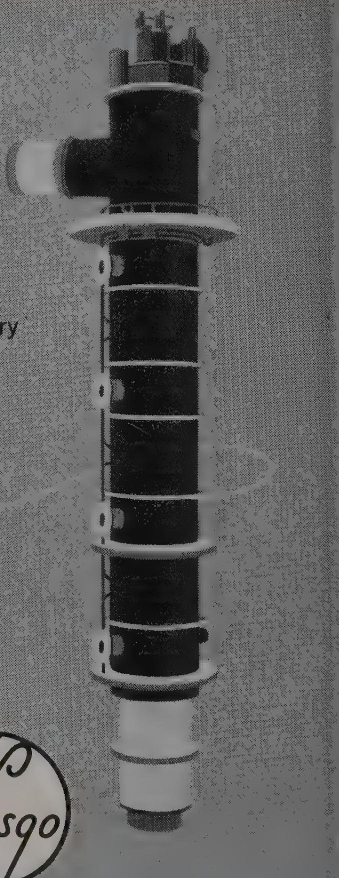
(*Continued on page 26*)

Where quality is the chief consideration WESGO Brazing Alloys—low vapor pressure, ultra pure!

Years of specialized experience in meeting the demanding requirements of vacuum tube manufacturers. This is what Wesgo offers you today in its complete line of brazing alloys for applications where quality factors outweigh cost.

Knowledge of the requirements of vacuum applications assures extra care in every step of Wesgo's manufacturing process—and superior alloys free from high vapor pressure elements and free from contaminants. High quality standards are maintained in conventional alloys, as well as a series of proprietary alloys developed specifically for vacuum systems use.





Wesgo alloys are available in wire, ribbon, sheet, powder, preforms—and the new Flexibraze slotted ribbon (illustrated) for R&D work and production economy.

Write today for a brochure describing these alloys or Wesgo's quality high alumina ceramics.

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SOLID STATE ISOLATORS

● PRODUCTS OF SPERRY RESEARCH

Specifications to meet every requirement within the UHF, communications and radar bands, and for commercial, laboratory and bench test applications.

New Lower Prices on Standard Models!

MINIATURIZED SOLID STATE DEVICES

ALL NEW!

Model No.	Frequency (GC)	Max. Power Peak (Kw)	Max. Power *Avg. (w)	Insertion Loss (db) Max.	Isolation (db) Min.	Max. VSWR	Transmission Line	Connectors Input	Connectors Output	Dimensions (in.) L	Dimensions (in.) D	Weight (oz.) Approx.
D44L7	1.25 -1.35	5	5	0.9	15.0	1.20	⅝″ coax.	N Ma	N Fe	6 39/64	25/32	6¼
D44L7-6	1.435-1.535	5	5	0.6	16.0	1.15	⅝″ coax.	N Ma	N Fe	6 39/64	25/32	6¼
D44L33-25	1.7 -2.3	5	10	1.0	13.0	1.20	⅝″ coax.	N Ma	N Fe	9 15/16	25/32	8
D44L33-23	2.12 -2.305	5	5	0.7	13.0	1.15	⅝″ coax.	N Ma	N Ma	5¼	25/32	5
D44S7	2.7 -3.1	5	5	0.9	15.0	1.20	⅝″ coax.	N Ma	N Fe	4 11/32	25/32	5
D44C7	5.4 -5.9	5	5	0.9	15.0	1.20	⅝″ coax.	N Ma	N Fe	4 11/32	25/32	5

*Assume 2:1 Max. Load VSWR

BROADBAND LOW POWER

ALL NEW!

Model No.	Frequency (GC)	Max. Power Peak (Kw)	Max. Power *Avg. (w)	Insertion Loss (db) Max.	Isolation (db) Min.	Max. VSWR	Transmission Line	Connectors Input	Connectors Output	Dimensions (in.) L	Dimensions (in.) W	Dimensions (in.) H	Weight (lbs.) Approx.
D44L5(72L2)	1- 2	10	10	1.0	10.0	1.25	⅝″ coax.	N Ma	N Fe	14⅛	1⅝	1 45/64	2 lb. 2 oz.
D44S5(72S2)	2- 4	10	10	1.0	10.0	1.20	⅝″ coax.	N Ma	N Fe	11 11/64	1⅝	1 45/64	1 lb. 7 oz.
D44C5(72C2)	4- 7	10	10	1.0	10.0	1.20	⅜″ coax.	N Ma	N Fe	6 7/16	1 41/64	1 23/32	1 lb. 4 oz.
D44X5(72H2)	7-11	10	10	1.0	10.0	1.25	⅜″ coax.	N Ma	N Fe	6 7/16	2¼	2⅜	1 lb. 6 oz.

*Assume 2:1 Max. Load VSWR

BROADBAND HIGH POWER

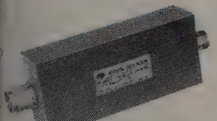
ALL NEW!

Model No.	Frequency (GC)	Max. Power Peak (Kw)	Max. Power *Avg. (w)	Insertion Loss (db) Max.	Isolation (db) Min.	Max. VSWR	Transmission Line	Connectors Input	Connectors Output	Dimensions (in.) L	Dimensions (in.) W	Dimensions (in.) H	Weight (lbs.) Approx.
D44L2-7	.95-2.35	10	200	1.0	10.0	1.25	⅞″ coax.	L-T Ma	L-T Fe	15⅜	2 1/16	3 9/16	5¾
D44L6	1.25-1.365	20	200	0.7	15.0	1.20	⅞″ coax.	N Ma	N Fe	11¾	2 1/16	3 9/16	5¼
D44S2	2.0 -4.0	20	200	1.0	10.0	1.20	⅞″ coax.	UG-46/U	UG-45/U	#12¼	2 1/16	3 9/16	4½
D44S2-5	2.35-5.0	10	200	1.0	10.0	1.25	⅞″ coax.	L-T Ma	L-T Fe	13	2 1/16	3 9/16	4½

*Assume 2:1 Max. Load VSWR

#Insertion Length

STRIP TRANSMISSION LINE



ALL NEW!

Model No.	Frequency (GC)	Max. Power Peak (Kw)	Max. Power *Avg. (w)	Insertion Loss (db) Max.	Isolation (db) Min.	Max. VSWR	Transmission Line	Connectors Input	Connectors Output	Dimensions (in.) L	Dimensions (in.) W	Dimensions (in.) H	Weight Approx.
D44J7	.400-.450	5	5	1.0	10.0	1.20	Strip	N Ma.	N Fe	7 37/64	3	1½	3 lbs. 7 oz
D44P1-5	.870-.990	5	5	1.2	20.0	1.20	Strip	N Ma.	N Fe	7 37/64	3	1½	3 lbs. 7 oz

*Assume 2:1 Max. Load VSWR

BROADBAND WAVEGUIDE

ALL NEW!

Model No.	Frequency (GC)	Max. Power Peak (Kw)	Max. Power #Avg. (w)	Insertion Loss (db) Max.	Isolation (db) Min.	Max. VSWR	Transmission Line	Connectors Input & Output	Dimensions (Length - Inches)	Weight (lbs.) Approx.
D41S5	2.6 - 3.95	10	10	1.0	15	1.10	RG 48/U	UG 53/U	11	12½
D41C5	3.95- 5.85	10	10	1.0	20	1.15	RG 49/U	UG 149 A/U	8	6¼
D41G5	5.85- 8.2	10	10	1.0	25	1.15	RG 50/U	UG 344/U	6⅛	3
D41X5	8.2 -12.4	10	10	1.0	30	1.15	RG 52/U	UG 39/U	6¼	2
D41U5	12.4 -18.0	10	10	1.0	30	1.15	RG 91/U	UG 419/U	*6	2

#Assume 2:1 Max. Load VSWR

*Tentative

Most of these units available from stock. We will welcome your inquiries for more complete information.

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Microline Instruments • Radar Test Sets • Systems Instrumentation • ***Solid State Devices and Materials*** *• Microwave Components and Antennas*

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Industry News

(*Continued from page 24*)

PRD PROMOTES HOPFER

PRD Electronics, Inc., Brooklyn, N. Y., microwave and electronic instrumentation manufacturer has announced the promotion of Dr. Samuel Hopfer to the position of manager of research, it was disclosed by Henry H. Michaels, Jr., president.

Dr. Hopfer was appointed to section head in 1949, became head of the Microwave Research department in 1956 and was promoted to manager of Advanced Engineering department in 1960.

Since joining PRD, Dr. Hopfer has been engaged in the fields of microwave theory and instrumentation. He has made contributions to the theory of coupling in multimode systems, the development of broadband transmission systems, the engineering of Ammonia Maser Oscillators, and the design of numerous microwave instruments.

—*mwj*—

MICROMEGA TO BUILD UHF PARAMPS

Micromega Corp., Venice, Cal., will undertake the development and production of UHF parametric amplifiers for tropo-scatter communications systems, according to terms of a $175,00 contract recently signed with Page Communications Engineers, Inc., Washington, D.C., a Northrop Corporation Subsidiary.

—*mwj*—

MARCY NAMED MANAGER AT ESCO

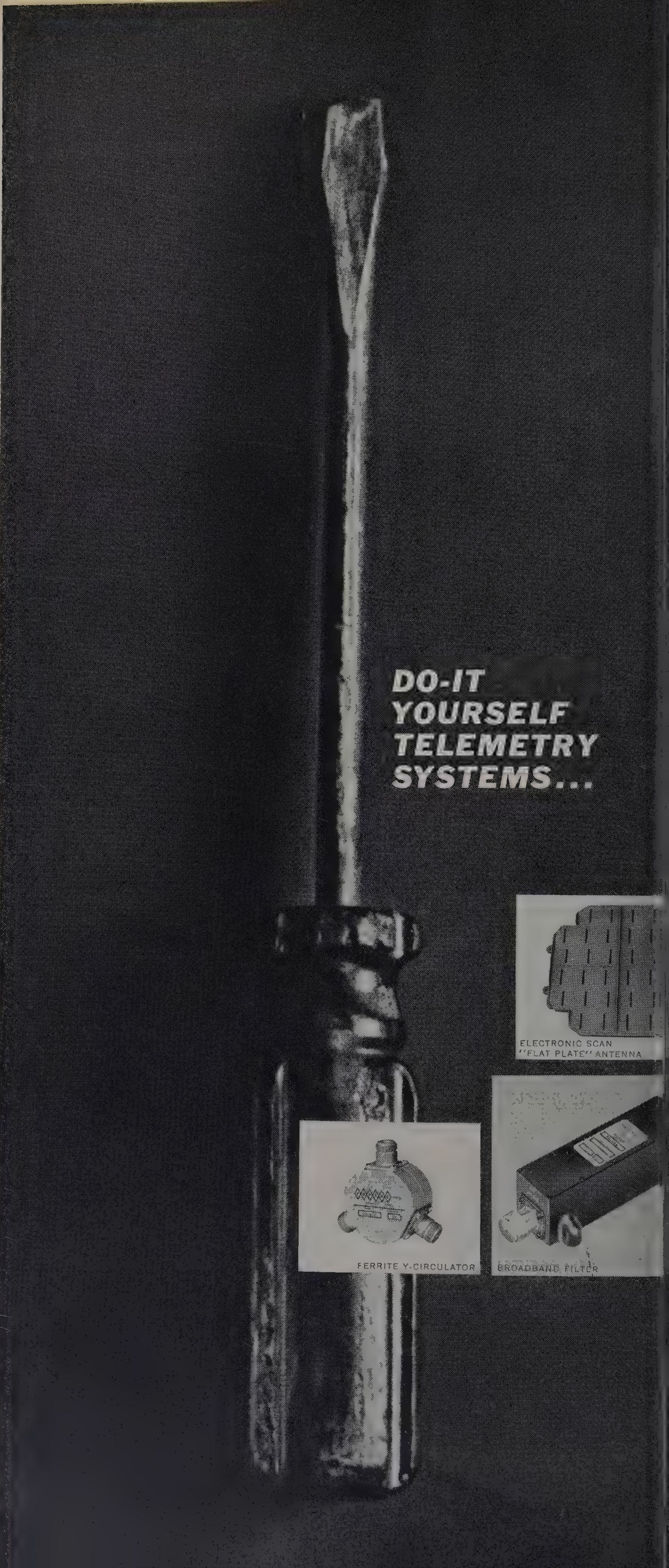
Appointment of William J. Marcy as General Manager of the ESCO Facility of Electronic Specialty Co., Los Angeles, Cal., has been announced.

Marcy, who has been with the company for the past five years was promoted to General Manager from his former spot as Corporate Sales Manager. His responsibility entails administration of the Avionics, Relay and Radiating Systems Divisions which are located in the Los Angeles Plant.

Richard M. Donley has been selected to fill the vacancy created by Marcy's promotion. Donley joined the company in 1959, and for the past year has handled the duties of Product Sales Manager of the Radiating Systems Division.

—*mwj*—

(*Continued on page 27*)


DO-IT YOURSELF TELEMETRY SYSTEMS...
ELECTRONIC SCAN "FLAT PLATE" ANTENNA
FERRITE Y-CIRCULATOR
BROADBAND FILTER

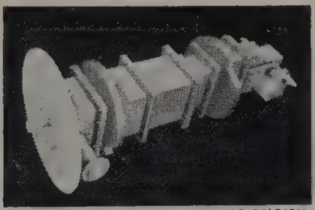
with
mponents
Rantec

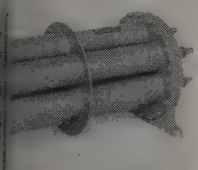
the past years, Rantec has concentrated a major part
research and development efforts in the design and
lopment of components and subsystems for telemetry.
tec is now able to offer the design engineer near complete
ms in today's 225-300 Mc and tomorrow's 1700-2300
bands. Here are components of amazing adaptability
he design of Rantec-reliable telemetry systems.

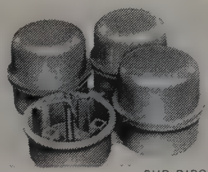
THE 225-300 MC SYSTEM *Antennas and arrays, for manual*
king and simultaneous lobing... Helical arrays... dipole diversity
ption arrays or feeds for large reflectors... these antennas have
used successfully in DISCOVERER, EXPLORER, PIONEER
ECHO projects... Antenna pedestals and servo mounts
metry multiplexers... units which combine two to six
smitters into one antenna... long term, hermetically sealed
uter space environment. Units are used in TITAN, POLARIS,
RCURY, DISCOVERER, SUBROC, X-15 and other projects

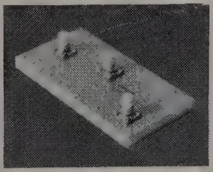
THE 1700-2300 MC SYSTEM *Simultaneous lobing and*
tronic conical scanning antennas... Horn arrays and slot arrays
ds for 6′ to 85′ diameter reflectors... used around the world
ers... coaxial and stripline... designed for rugged ground and space
ironments... Multiplexers... two to ten channel applications
rid assemblies... to be used with simultaneous lobing systems
ermit tracking by providing sum and difference channel outputs
l channel rotary joints... Control and display panels...
irculators... broad-band, compact... for use with parametric
plifiers... Coaxial isolators... ferrite switches

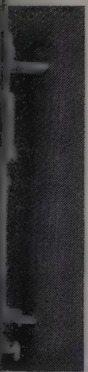
2 CHANNEL MULTIPLEXER

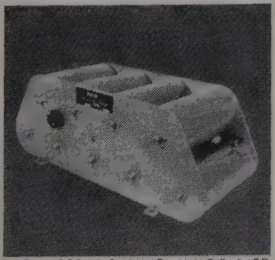

TRANSMITTING-TRACKING FEED FOR 85′ DISH

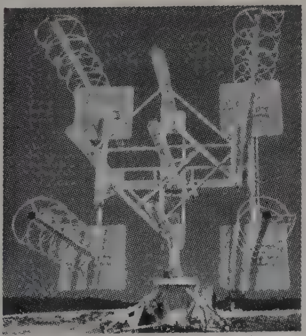

6 CHANNEL MULTIPLEXER

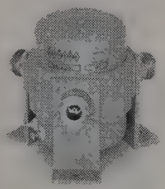

CUP-DIPOLE

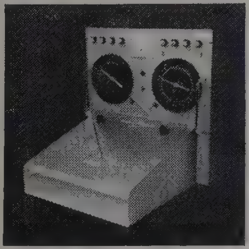

STRIPLINE DIPLEXING FILTER


OTARY JOINT


LOW-LOSS, 3-CHANNEL MULT PLEXER


MULTI-FREQ. HELIX TRACKING ARRAY


FERRITE SWITCH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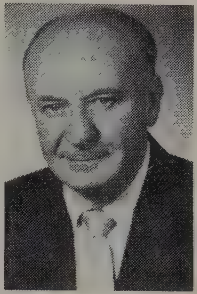
omplete specifications for each component and subsystem are available.
antec engineers will be happy to work with your telemetry team in the application
f these components to the total system.

Rantec Corporation, Calabasas, California

Industry News

(*Continued from page 26*)

WUNDERLICH NAMED STAFF CONSULTANT



Norman E. Wunderlich has been named Staff Consultant of Intercontinental Electronics Corporation (INTEC), Westbury, N. Y. which is an affiliate of the French firm Compagnie Generale de Telegraphie Sans Fil (CSF), Paris and handles the manufacturing and marketing of the CSF products in the United States and Canada.

Mr. Wunderlich was also recently elected Vice President of Allen Avionics, Inc., of Mineola, L. I., New York manufacturers of delay lines, filters and special transformers. Allen has just completed the construction of an additional new plant and office building of 24,000 square feet.

—mwj—

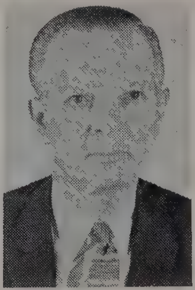
HARDING NAMED TO NORTHEASTERN BOARD

Henry W. Harding, president of Laboratory For Electronics, Inc., Boston, Mass., was one of four executives appointed to serve on the advisory board of Northeastern University's Center for Management Development it has been announced by Dr. Asa S. Knowles, N. U. President.

The 17-member board advises the University in the formation of programs for the training of middle management personnel at the Center's headquarters in Andover, Mass.

—mwj—

HENDERSON APPOINTED TO NEW POST AT FXR



William J. Henderson has been promoted to the new post of general sales manager of FXR, Inc., Woodside, N. Y., Henry Feldmann, chairman and president of the company, announced.

In this capacity he will be responsible for marketing and sales activities for all FXR divisions.

Mr. Henderson joined FXR last fall. He was formerly with Westinghouse Electric Corp., Sperry Gyroscope Co. Division of Sperry Rand Corp., and International Telephone & Telegraph Co.'s Federal Division. Previously he was director of advanced projects for General Bronze Electronics Co.

—mwj—

(*Continued on page 34*)

◆ **Circle Reader Service Card 23**

" UNTIL . . . SOMEONE FINDS SOME BETTER METHOD . . .
IT . . . CAN BE EXPECTED TO BECOME
OF INCREASING IMPORTANCE . . . "

the role of matrix analysis

M. C. PEASE ASSOCIATE EDITOR, *the microwave journal*

Most microwave component engineers, at some time or other in their education, are exposed to the elements of matrix algebra. And even the few that escape at first usually find it necessary eventually to be able to read the literature.

It is then, perhaps, worthwhile to consider why this is so. What can matrix algebra do that other techniques will not? Is it a valid answer to a genuine problem, or is it an esoteric fad chiefly useful for confusing the uninitiated?

As to its ability to handle various theoretical problems of networks and electron beam devices, there can be no question. Network problems are, almost by definition, linear. Electron beams are non-linear but can be usefully approximated by linear methods. In fact, their equations are so thoroughly non-linear that only a handful of exact solutions are known. It is fortunate that linear approximations to the beam equations do prove to be adequate for many purposes.

The most general operator which maps in linear fashion a finitely dimensioned space onto another can be written as a matrix. The elements of the algebra, therefore, are adequate to handle any finitely dimensioned linear problem. Furthermore, various means of combining these elements (multiplication, etc.) have been sufficiently studied so that an algebra suitable to any particular problem can usually be found.

Hence, matrix algebra, as presently understood, is, in fact, able to handle a great variety of problems that are important to the microwave engineer.

But this still does not answer the question "why bother?" It is possible to swat a mosquito with a sledge hammer, but it is not recommended practice.

In particular, it can be said that anything that can be computed or proven by matrix methods can be handled by ordinary algebra. After all, the calculation of an observable quantity eventually comes down to the ordinary manipulation of ordinary numbers (at least ignoring the use of modulo two arithmetic for problems of logic). This is true even if the preliminary manipulation of the abstract concepts is by way of matrices, quaternions, vector algebra, or any other esoteric discipline.

We can, in fact, state a principle here which might l labeled the "invariance of truth." This principle sa that the conclusions are inherent in the assumptions, i dependent of the formalism that is used. Having decid on the appropriate mathematical model of the physic situation, and having stated the boundary or initial co ditions that interest us, then what *can* be proven or calc lated is independent of the discipline used. What can l done by one formalism can also be done by any other a propriate one.

Matrix algebra does not allow us to prove anythin that could not be proven without it.

The emphasis, here, is on the word "can." The princip has nothing to say about convenience or any other su jective values. It merely asserts what is possible, an states that this is independent of the formalism.

So we might still hope that matrix methods will short the tedium of calculating the numerical answer to a spec fic answer. Granted that the calculation can be done other ways, perhaps the use of matrices will shorten th process.

Unfortunately, there is another principle that can b invoked that has been called the "conservation of diff culty." This principle states that no matter what forma ism is used to obtain a given amount of data from given set of conditions, there will always be needed abou the same number of additions, subtractions, multiplic tions, and divisions.

Obviously, this principle is not on as sound a philoso phic basis as the former one—nor can it be stated a precisely. However, as a generalization of what is norma ly experienced, it has behind it the authority of muc desperate head scratching over the centuries.

So it is unlikely that the use of matrix algebra wi have much effect on the tedium of numerical calculation It may be—and often is, in fact—useful in systematizin the computation and therefore reducing the chance c error, but it will not provide any reduction of effort.

The principle as stated, however, contains one limita

(*Continued on page 30*)

ix *Styroflex®* *Coaxial Cables* on One Tower

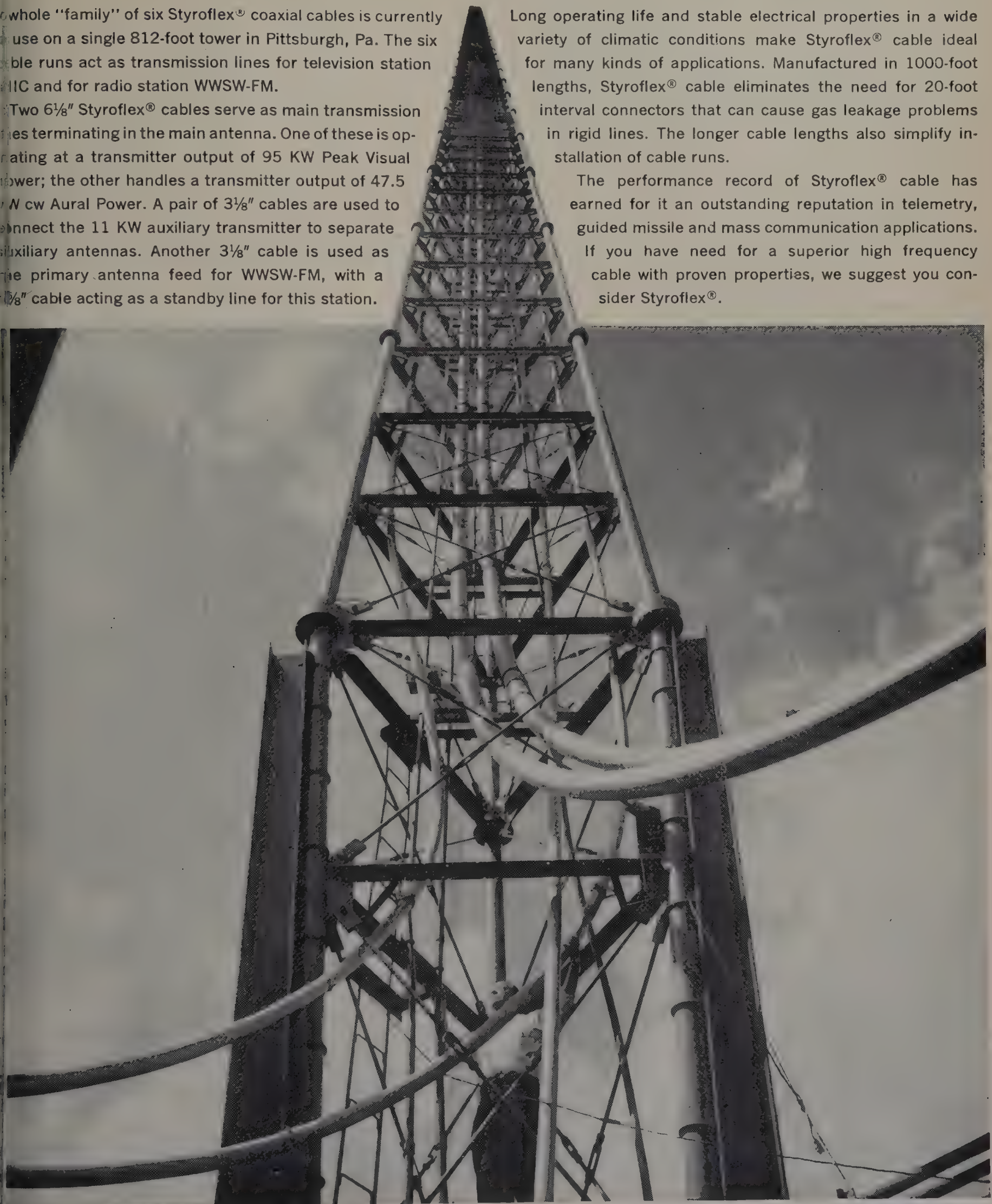
...feed antennas for WIIC (TV) and WWSW-FM in Pittsburgh!

whole "family" of six Styroflex® coaxial cables is currently use on a single 812-foot tower in Pittsburgh, Pa. The six ble runs act as transmission lines for television station IIC and for radio station WWSW-FM.

Two 6⅛″ Styroflex® cables serve as main transmission es terminating in the main antenna. One of these is op-ating at a transmitter output of 95 KW Peak Visual wer; the other handles a transmitter output of 47.5 N cw Aural Power. A pair of 3⅛″ cables are used to nnect the 11 KW auxiliary transmitter to separate xiliary antennas. Another 3⅛″ cable is used as e primary antenna feed for WWSW-FM, with a ⅛″ cable acting as a standby line for this station.

Long operating life and stable electrical properties in a wide variety of climatic conditions make Styroflex® cable ideal for many kinds of applications. Manufactured in 1000-foot lengths, Styroflex® cable eliminates the need for 20-foot interval connectors that can cause gas leakage problems in rigid lines. The longer cable lengths also simplify installation of cable runs.

The performance record of Styroflex® cable has earned for it an outstanding reputation in telemetry, guided missile and mass communication applications. If you have need for a superior high frequency cable with proven properties, we suggest you consider Styroflex®.



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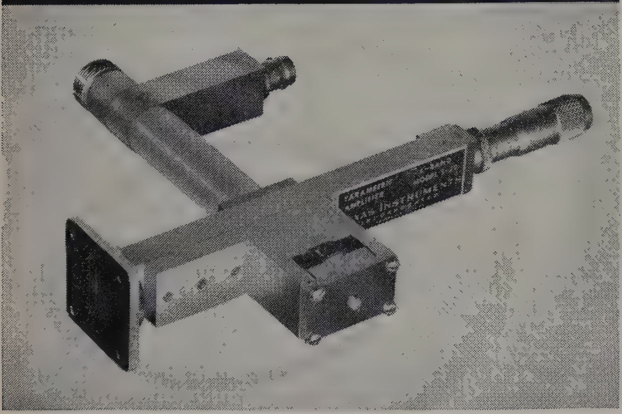
with bandwidths up to 75 mc at 15 db gain!



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Broadband, parametric amplifiers for applications at L, S, C, and X band are available now from Texas Instruments. The S-band model, designed with a TI XD-500 gallium arsenide diode, gives bandwidths up to 75 mc at 15db gain. Gain variation is no greater than 3 db over temperatures ranging from −40°C to +50°C, and the unit meets the vibration requirements of MIL-E-5400D. Noise figure, including circulator loss is 3 db. The associated circulator is a miniaturized, three-port ferrite unit with 0.5 db insertion loss and 20 db isolation.

TYPICAL MODEL S-22 SERIES SPECIFICATIONS	
frequency	2.8 to 2.96 Gc
bandwidth	40 mc
gain	15 db
noise figure (includes circulator loss)	3 db
pump frequency	X band
diode	Texas Instruments XD-500 $F_c \geqq 70$ kmc at −2 v bias
temperature range	−40°C to + 50°C
vibration	per MIL-E-5400D
pump power	50 mw

For details on TI's S-band amplifiers, write for Bulletin No. DLA-1217. For information on specific applications at all frequencies, contact MARKETING DEPARTMENT.

TEXAS INSTRUMENTS
INCORPORATED
APPARATUS DIVISION
P. O. BOX 6015
DALLAS 22, TEXAS

PEASE

(*Continued from page 28*)

tion—and it is an important one. If, of two computation schemes, one gives more answers than are wanted, th other may save considerable effort. Where the sheer labo involved is an important factor, it is important that th procedure used shall *not* answer questions that have no been asked.

This question of economy is important, and seems be becoming more so. The trend in electron beam device at least, is towards additional complication of process— hopefully, without additional complexity of structu The theory of the traveling wave tube, at least for initi purposes, can be adequately developed by considerin four waves—the fast and slow space charge waves c the beam, and the forward and backward waves on th circuit. The equations then, written in matrix form, ge erate a 4 x 4 square matrix. The first equation that mu be answered is whether the device will amplify, and ho fast. The answer to this question involves finding the ap propriate root of the "secular equation," which is th "characteristic equation" of the matrix. Hence, the prob lem resolves into the expansion of a 4 x 4 determinan

To completely expand a 4 x 4 determinant, even in th absence of any zeros, is not difficult. It may not be som thing that one does for the sheer joy of it, but neither it a major undertaking. There are, to be exact, 24 (4 terms in the expansion.

If, now, we provide a pumping signal so that our TW becomes a parametric amplifier, then we have at lea twice as many waves—i.e., four waves at the signal fr quency and four at the idle frequency. The correspondin determinant is now 8 x 8, and if there were no zeros, th total number of terms in its complete expansion is 40,32 (8!). The problem has gone from the simple to the "ou of-this-world" category!

Things are not really this bad, of course. The matri has many terms that are zero. Furthermore, the pumpin action is separated from the circuit, so that the proble involves the cross-coupling only of the beam wave Hence this particular problem can be handled.

On the other hand, things are actually much wors For in this particular case, it has been found that tw frequencies are not enough. For noise analysis one nee to consider at least four frequencies (signal, idle, an pump plus signal and idle) and maybe more.

The full analysis of this problem can very easily g completely out of hand by the sheer number of ter involved.

Actually, of course, electron beam parametric theo and practice is currently concentrating on the use of th cyclotron waves rather than the space charge ones. Th apparently avoids coupling of the higher frequencies, that attention can be limited to the signal and idle fr quencies alone.

The cyclotron waves arise when transverse electro motions are considered. This additional freedom of th electron now allows six waves on the beam—the tw cyclotron waves, two space charge waves, and two "sy chronous" or displacement waves. Hence, the full descri tion of the unpumped beam at one frequency involves 8 x 8 matrix, from the six beam waves plus the two ci

(*Continued on page 32*)

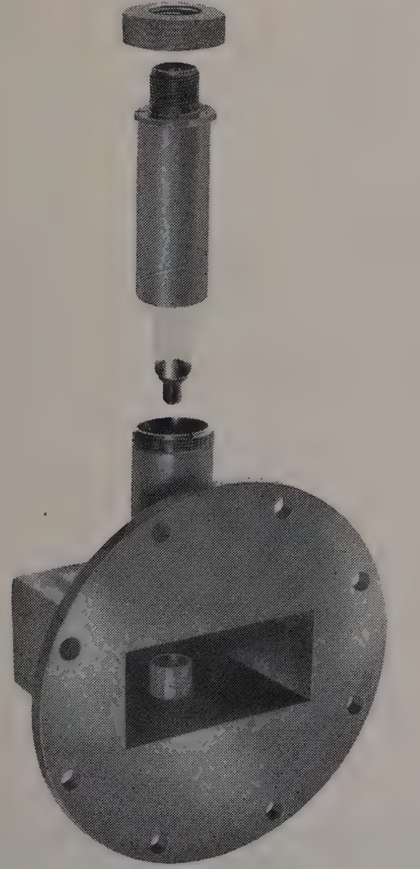
Circle Reader Service Card 25

Acoustical noise: 85 db. at 6 inch distance

For noise at microwave frequencies, too, there's an ideal device in a small package. It's the Litton L-2000 series of miniature gas discharge noise sources. Use them for automatic monitoring of the performance and sensitivity of modern radar systems. They're available to cover the most-used frequency bands and come in a variety of mount configurations.

The series features a shielded cathode, low modulator drain, and field-replaceable tube insert. Rugged. Insensitive to a wide range of ambient temperatures. Compactly engineered for demanding air and ground environments. Economical because of replaceability, plus added advantages of logistic simplicity and ease of maintenance.

BIG NOISE FROM A SMALL SOURCE



The tube pictured here is the single-ended L-2000 with the LR-2000 insert, specified for a recent generation of FAA airport surveillance radars and for a variety of well-known "S-band" military systems.

For more data on these or other precision gas tube products, write Litton Industries, Electron Tube Division, 960 Industrial Road, San Carlos, California. Or telephone LYtell 1-8411.

GAS NOISE TUBES

Type Number	Frequency Range (megacycles)	Excess Noise Ratio (db)	Nominal Operating Current (ma)	Nominal Operating Voltage (volts)	RF Coupling
L-2008	200-250	18.5 ± 0.5	25	200	¾″ coax*
L-2013	570-630	18.5 ± 0.5	25	200	¾″ coax*
L-2006	1200-1400	18.5 ± 0.5	50	175	¾″ coax**
L-2000(R)	2700-2900	18.5 ± 0.2	75	30	RG-48/U WG*
L-2018(R)	2700-2900	15.5 ± 0.2	75	35	RG-48/U WG*
L-2011(R)	3300-3700	18.4 ± 0.2	150	30	RG-48/U WG*
L-2009(R)	3400-3700	15.5 ± 0.5	125	20	RG-48/U WG*
L-2007	2000-4000	18.5 ± 0.5	85	135	¾″ coax**
L-2010	2000-4000	15.0 ± 0.5	40	60	¾″ coax**
L-2001(R)	5400-5900	13.0 ± 0.5	100	55	RG-49/U WG**
L-2002(R)	7500-8600	14.5 ± 0.5	100	40	RG-51/U WG**
L-2003(R)	8500-9600	14.5 ± 0.5	100	45	RG-52/U WG**
L-2004(R)	8500-9600	18.5 ± 0.5	100	45	RG-52/U WG*
L-2017(R)	8970-9190	18.5 ± 0.5	100	45	RG-52/U WG*
L-2005	16000-17000	18.5 ± 0.5	55	55	RG-91/U WG*

(R) denotes replaceable gas tube insert
*single ended mount
**double ended mount

LITTON INDUSTRIES
Electron Tube Division
MICROWAVE TUBES AND DISPLAY DEVICES

Circle Reader Service Card 26

(*Continued from page 30*)

cuit waves. The pumped case, therefore, involves a 16 x 16 matrix.

Again, fortunately, the matrix contains many zeros. Also, the analyst generally feels justified in omitting those waves that are badly out of synchronism. Since this is true of most of the waves, the problem can be made tractable.

This latter simplification has its dangers, however. It involves introducing approximations at the start of the analysis. It would certainly be preferrable to make them at the end when their effects can be quantitatively estimated. However, it is unavoidable, if things are to be held at all in bounds, until someone finds an analytic method that avoids the necessity of expanding the determinant.

Without going further into the details of these problems, we can, then, recognize the necessity for economical analysis—i.e., for minimizing the amount of unwanted information that is obtained incidentally to answering the important questions.

The analytic process as outlined is not, in fact, an economical one. The complete expansion of the characteristic determinant supplies much more information than is wanted. It gives the effect on all the eigenvalues, not only on the one that is amplifying. And it gives the effect on the eigenvalue of interest of all the couplings, not only those of principle significance. So, within the limits of the conservation of difficulty, there is still the possibility of reducing the problem drastically by findi means of calculating *only* what is wanted.

The recent shift of attention from relatively simp interactive situations to those involving large numbe of waves is bringing this problem into sharp focus. is rapidly becoming of vital importance that econom means of analysis be found.

The question, then, is whether matrix algebra is t means for finding economic methods. This is a questi that concerns not the deductive processes of t mathematical discipline itself, but the inducti processes of the mathematician. For, as far as what c be done, the invariance of truth applies, and any partic lar discipline, providing it deals with terms that are all appropriate, is capable of proving economic method But the ability of the mathematician to find these metho is a wholly different thing. The problem concerns t mathematician, rather than the mathematics.

Are matrix methods appropriate to this purpose? appears that they are. The question of why cannot b answered fully, but certain observations can be made.

First, we may note the similarity of this type of prob lem to some that arise in quantum mechanics. The qua tum mechanician is often concerned with the effect coupling together large numbers of "eigen-states." T analogy to the electronic problem of coupling togeth a large number of waves is obvious. The analogy fails detail for various reasons (e.g., because the matrices electronics are not usually hermitian), but it is at lea suggestive that quantum physicists have found matr algebra a very powerful tool.

(*Continued on page 34*)

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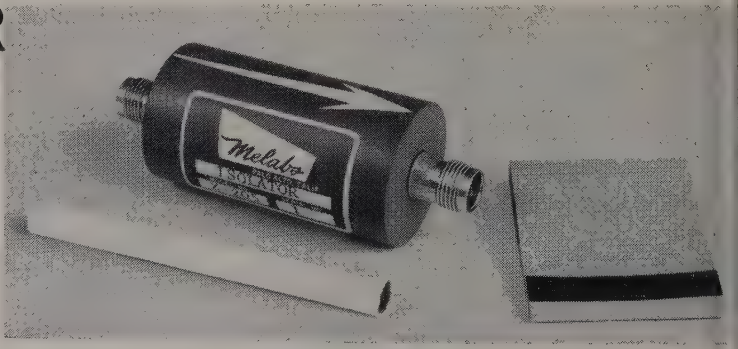
AND TIME TO LIGHTEN UP!

An **ISOLATOR**

only 4 ounces light! Only 3½" long, including connectors!



Your every isolator problem involving size and weight is solved with this Melabs Model X-205: 5.4 to 5.9 GC • max. insertion loss (at band ends) 1.0, typical center, 0.8 • isolation (min. at band ends) 18.0 (typical center, 25.0) • input VSWR max. 1.25:1 • power, 5 W av. • TNC connectors —all this... and magnetically shielded!

Delivery, specified quantities, available from stock: Melabs X-205 Isolator, $320.00.

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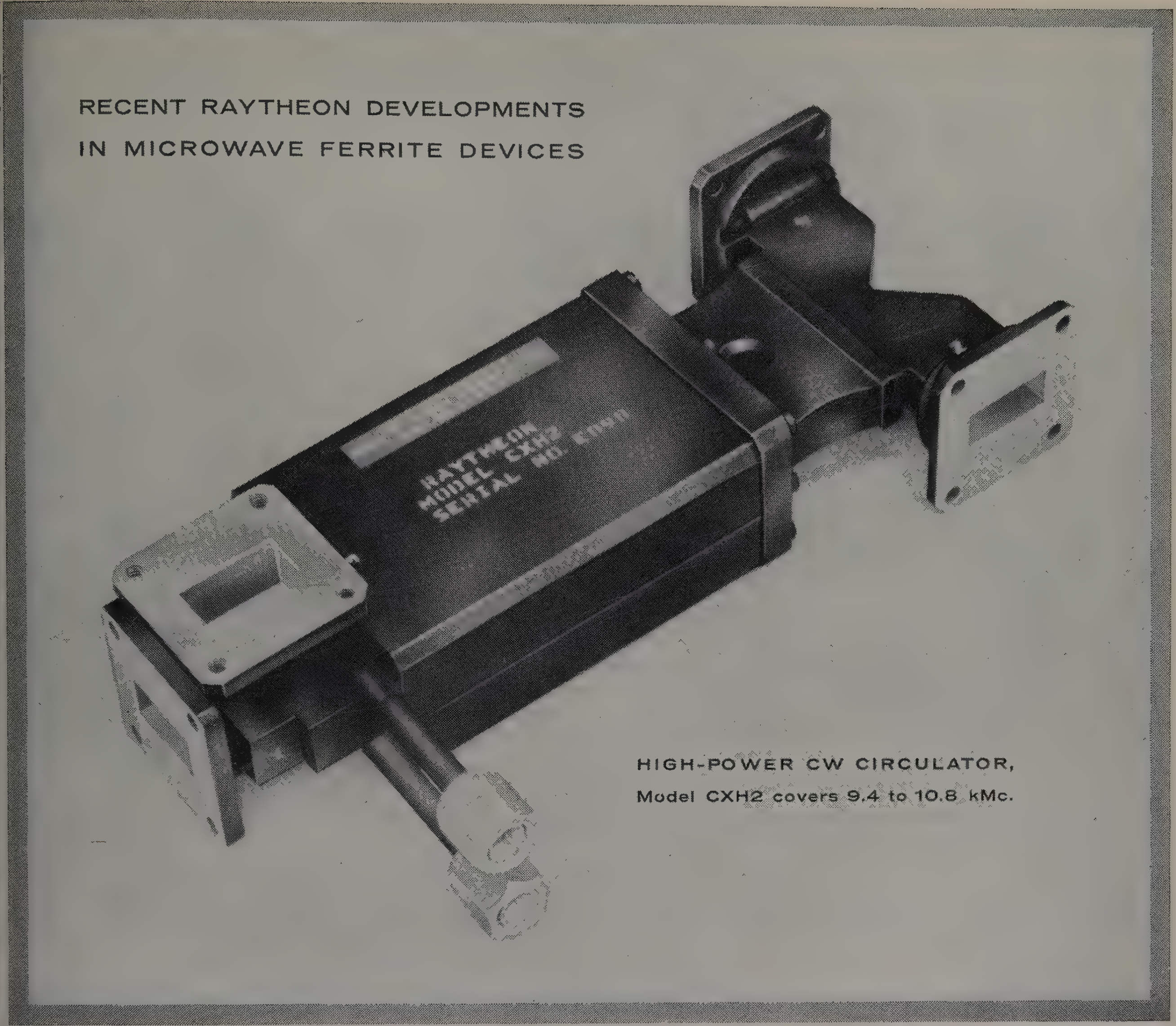

RECENT RAYTHEON DEVELOPMENTS
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HIGH-POWER CW CIRCULATOR,
Model CXH2 covers 9.4 to 10.8 kMc.

Versatile X-band circulators handle cw power in excess of 10kW

New high-power ferrite device provides over 20 db isolation; can be used as isolator with suitable auxiliary loads.

An advanced line of Raytheon high-power circulators keeps abreast of new X-band tube developments.

Typical of these compact units is the CXH2 covering 9.4 to 10.8 kMc with a continuous power rating of 10kW. Isolation is 20 db minimum, insertion loss is 0.2 db maximum and VSWR is 1.15 maximum.

Used as an isolator—in conjunction with suitable auxiliary loads—the CXH2 will handle continuous power levels to 10 kilowatts with a back-to-front ratio greater than 100:1. Similar units are available for use at high peak power levels.

For complete details on this and other significant developments in high-power microwave ferrite devices, please write to Special Microwave Devices Operation, Raytheon Company, Waltham Industrial Park, Waltham 54, Massachusetts.

TYPICAL SPECIFICATIONS • MODEL CXH2

Frequency	9.4—10.8 kMc
Power	10kW (cw)
Isolation	20 db min.
Insertion loss	0.2 db max.
VSWR	1.15 max.
Length	9 3/16 in.
Flanges	UG 39/U
Waveguide	RG 52/U
Weight	Less than 4 lbs.
Water cooled	0.75 gpm.

RAYTHEON

RAYTHEON COMPANY

SPECIAL MICROWAVE DEVICES OPERATION

Circle Reader Service Card 28

PEASE

(*Continued from page 32*)

Secondly, matrix algebra offers a compact formalism for this type of problem. A whole set of equations can be written as a single one, and operations that are complex in detail can be carried out formally with little trouble.

On the other hand, it is not too compact. The formalism of tensor analysis is often even more compact. But often, too, tensor equations are so compact that it is very difficult to obtain any concept of what they mean without translating them back into less compact form.

There appears to be an optimum degree of compactness for the human mind. How close matrix algebra is to this optimum level is a matter for the individual, but the evidence seems to indicate it is not too far from optimum for many purposes.

Finally, and perhaps most fundamentally, matrix algebra is, conceptually, a discipline which considers the entire structure as a unit. In the conceptual sense, it deals in multi-channel processes without separating them.

This can be illustrated by a rather trivial example. If we consider a ladder network, we can calculate its behavior by a step-by-step application of ordinary algebra. When we do so, we are, in effect, first calculating the response at one point to a voltage at another, and then the response due to a current, and then superimposin the two. Since the system is linear, this is a valid metho the principle of superposition being rigorously appl cable. Using matrix methods, the actual calculations ma duplicate this process. However, the resultant matrix ma be conceived of as describing the total response to bot the voltage and current, considered as a single unit.

The actual numerical calculations are not simplifie or, indeed, much altered, but the symbolic significan is greatly altered.

For the problem cited, this change may not appear make much difference. For more complicated situation we suspect it does have major significance in terms of th subjective attitude it generates and implements. Whe the problem is to intuit what can be found and the pract cal means of analysis, we suspect that this trick of redu ing a multilevel process to a single inclusive form is c vital significance. Certainly, this point of view has bee of great value in the past, and it appears that it will b of even greater value in the future.

So, as to the question of "wherefore matrix algebra, there does seem to be valid reason for its use. The in creasing complexity of the problems that concern theor ticians in electron devices argue the increasing need fo a discipline of this sort. Until and unless someone find some better method—which, if one is found, will prob ably appear even more esoteric—the importance of matri analysis can be expected to become of increasing in portance in the study of new electronic devices.

Industry News

(*Continued from page 27*)

LYNCH DELIVERS EQUIPMENT TO SIGNAL CORPS

D. E. Campbell, president, Lynch Communication Systems, Inc., San Francisco, Cal., says his firm has just completed delivery of a $200,000 order of in-band signaling communication equipment to the United States Signal Corps.

Campbell said the Signal Corps order was for Lynch commercial type equipment, their B820 in-band signaling system which uses an exclusive Lynch development, a multi-tone, frequency shift which provides either dial signaling or ringdown signaling at the flip of a switch.

—mwj—

SYLVANIA NAMES KONKOL GENERAL MANAGER

Sylvania Electric Products Inc., Mountain View, Cal., has announced the appointment of George Konkol as general manager of Microwave Device Operations. Mr. Konkol has been general manufacturing manager of Sylvania's Parts Division at Warren Pa., since 1959.

Mr. Konkol joined Sylvania in 1948 as an industrial engineer at the company's Receiving Tube Operations at Emporium, Pa. In 1951 he was appointed general foreman, and the following year was named manufacturing superintendent. In 1954 he was transferred to Warren as manager of the Parts Division's wire and weld plants.

A native of Chicago, Mr. Konkol attended the Illinois Institute of Technology and Purdue University, where he received a BS degree in aeronautical engineering in 1948. Under a Sloan Fellowship, he received an MS degree in industrial management from the Massachusetts Institute of Technology in 1954.

—mwj—

ELECTROSPACE ACQUIRES GENERAL HERMETIC SEALING

William Brown, President of Electrospace Corporation, has announced that the total assets and manufacturing facilities of General Hermetic Sealing Corp., Valley Stream, New York, have been acquired by Electrospace Corporation.

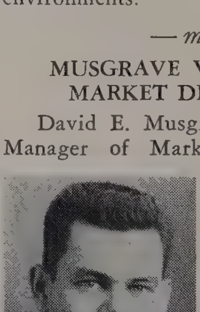
This acquisition is one of the first in a planned program of acquisitions. Additional acquisitions, designed to implement the total systems capabilities of Electrospace Corporation, are nearing completion.

Electrospace Corporation was formed as a nucleus of a wholly-owned, integrated organization dedicated to the design, development and manufacture of electronic systems and sub-systems in the fields of instrumentation, guidance, controls and communications for missiles, space vehicles, airborne and ASW systems, including the ground support functions.

GHS was established in 1951 as General Hermetic Sealing Corporation to provi "idea to finished product" services f electronic components and systems whi required complete isolation from outsi environments.

—mwj—

MUSGRAVE WILL MANAGE MARKET DEVELOPMENT



David E. Musgrave has been name Manager of Market Development f Sperry Electron Tube Division Sperry Rand Corp Gainesville, Fl According Division Gener Manager John Whitford, who a nounced the ap pointment, Mus grave will opera from the Division headquarters.

Among the responsibilities encompasse by Musgrave's newly created post are th general areas of advertising, sales promo tion, marketing planning, and marketin administration.

Musgrave joined Sperry in Decembe 1959, coming here from his former po as Product Promotion Specialist with th General Electric Co. in Ft. Wayn Indiana.

A native of Connellsville, Pa., Musgrav holds a BSEE degree from Carnegie Inst tute of Technology. He was graduate in 1948.

—mwj—

(*Continued on page 36*)

Bendix Craftsmanship at work for you

TWO-67
MADE IN U.S.A.
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AVAILABLE TYPES

Solenoid Focused

Type TWO-88 with frequency range of 30 KMC to 40 KMC
Type TWO-75 with frequency range of 40 KMC to 50 KMC
Type TWO-67 with frequency range of 49 KMC to 59 KMC
Type TWO-82 with frequency range of 50 KMC to 60 KMC
Type TWO-66 with frequency range of 61 KMC to 71 KMC
Type TWO-83 with frequency range of 65 KMC to 75 KMC
Type TWO-85 with frequency range of 70 KMC to 85 KMC
Type TWO-87 with frequency range of 85 KMC to 100 KMC
Type TWO-90 with frequency range of 100 KMC to 120 KMC
Type TWO-93 with frequency range of 120 KMC to 140 KMC

Available now permanent magnet focused type TWO-89 with frequency range of 50 KMC to 60 KMC

LARGEST LINE OF MILLIMETER WAVE LENGTH BWO

Bendix® BWO tubes for higher frequency transmission. These Backward-Wave Oscillator Tubes—exclusive with Bendix—generate microwave energy over the largest continuous frequency range. Ideal for advanced multichannel telephone and television systems, microwave spectroscopy, high definition short range radar, highly directive communications, and many other applications needing low power, voltage-tuned millimeter wave length radio frequency energy. Write today for complete information.

ELECTRICAL DATA

Frequency Range	30 KMC-120 KMC (see specific type)
Anode Voltage	1000-4000 volts
Power Output	Up to 20 mw average (depending on frequency)
Beam Current	10 MA
Magnetic Field	2000 gauss
Heater Voltage	6.3 ±10%

MECHANICAL DATA

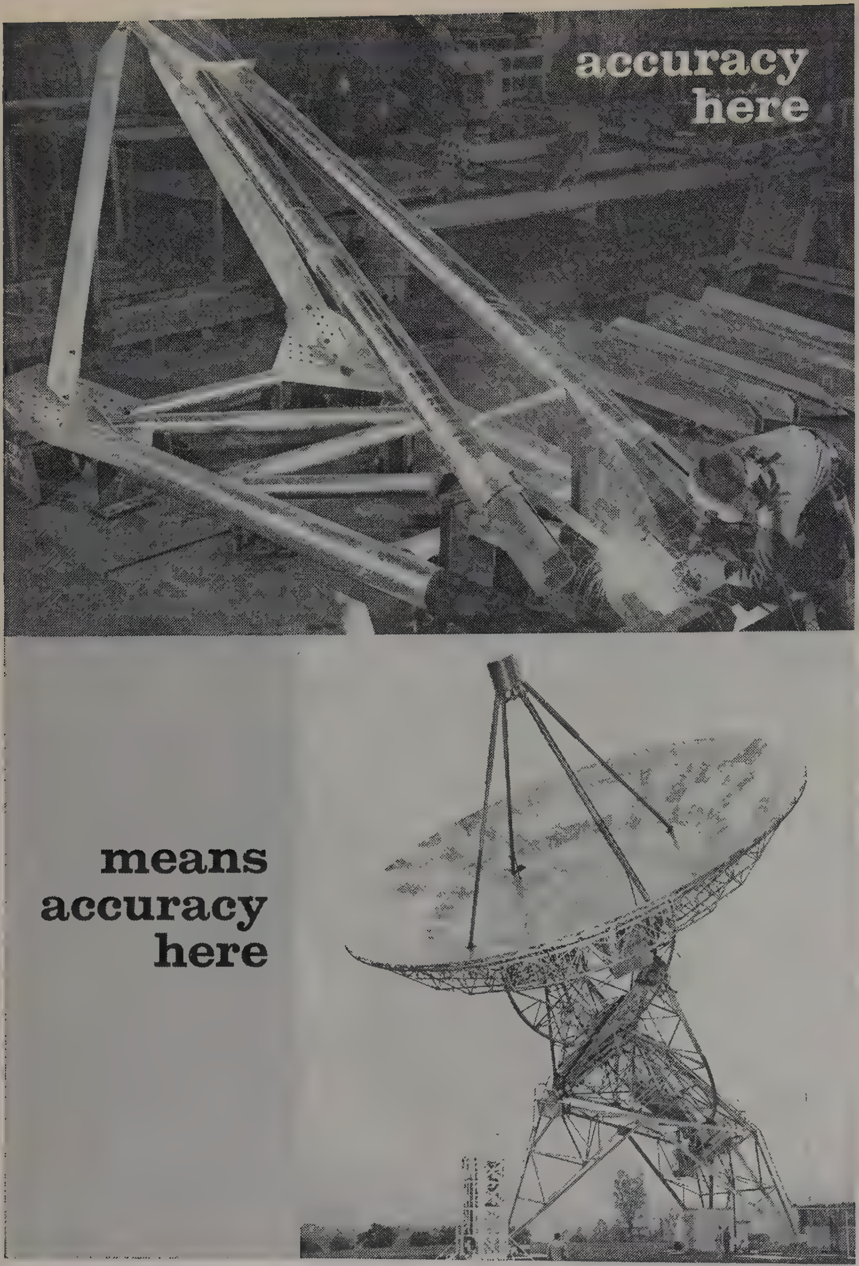
Output Flange	Special adapter to RG-98/U (50-75 KMC)
Maximum Diameter	0.625"
Length	8"
Mounting Position	Any
Weight	5 oz.*

*Without magnet (tube only). Magnets are available.

ELECTRON TUBE PRODUCTS

Red Bank Division
EATONTOWN, NEW JERSEY

THE Bendix CORPORATION



■ The high degree of accuracy required in antennas and radio telescopes demands the finest precision manufacture. For example, assembling massive tetrahedrons like these to within thousandths of an inch requires a "master craftsman" attitude and years of training and experience. ■ Blaw-Knox men have this skill and experience—backed by the finest facilities. ■ Having these facilities and talents available, Blaw-Knox engineers design all types of antennas with maximum efficiency at minimum weight. All designs are determinate. Nothing is left to trial and error. ■ Blaw-Knox has designed and built most of the large antennas now in service . . . fabricates in steel, special alloys, and aluminum . . . designs to fit your needs or builds to your specifications. Complete research, engineering, testing and fabricating facilities are at your disposal. A letter or phone call will get immediate attention. Blaw-Knox Company, Pittsburgh 38, Pennsylvania.

BLAW-KNOX
ANTENNAS

BLAW-KNOX

Blaw-Knox designs and manufactures for America's growth industries: METALS: Rolling Mills • Steel Processing Lines • Rolls • Castings • Open Hearth Specialties • PROCESSING: Process Design, Engineering and Plant Construction Services • Process Equipment and Pressure Piping • CONSTRUCTION: Concrete and Bituminous Paving Machines • Concrete Batching Plants and Forms Gratings • AEROSPACE: Fixed and Steerable Antennas • Radio Telescopes Towers and Special Structures • POWER: Power Plant Specialties and Valves

Circle Reader Service Card 30

Industry News

(Continued from page 34)

ELECTRONIC TECHNIQUE AIDS RADARS, COMPUTERS

An electronic technique which could improve the versatility and precision of radars and analog computers, has been perfected by the Sperry Gyroscope Company, Great Neck, N. Y.

The technique will make it possible for anti-missile fire control or commercial air traffic radars to track simultaneously a great number of airborne targets over a single receiving channel.

It also can overcome certain problem solving and timing limitations of analog computers by simplifying the computer and reducing the probability of even minute errors, according to Sperry scientists.

The basic development is a circuit called a broadband analog divider. In radars it removes the need for individual signal processing channels for each prospective target and eliminates time lags now necessary for running correction signal through complex feedback circuits.

—mwj—

MELABS NAMES TWO BRANCH MANAGERS

Two new managers, William C. Hennings and Hugh L. Gottfried, have been appointed to head recently-established branches of Melabs, microwave engineering firm.

Mr. Hennings has been appointed manager of the company's new Space System Branch. He previously was manager of the Receiver Development Branch.

Hugh L. Gottfried was named manager of the new Reconnaissance System Branch. He previously was manager of the Countermeasures Branch.

Prior to joining Melabs in 1957, Mr. Gottfried was associated with the U.S.N. Radiological Defense Laboratory and the Electronic Defense Laboratory.

—mwj—

ROWLAND JOINS ANTENNA SYSTEMS

Antenna Systems, Inc., Hingham, Mass., announces the appointment of Howard J. Rowland as Director of Research and Development. He will be responsible for basic research and study programs on microwave theory, propagation, and techniques.

Previously, Mr. Rowland was Director of the RF Division at D. S. Kennedy & Co. where he was responsible for the design and development of all RF components as well as research in advanced engineering techniques. He has also worked for Pickard & Burns, and Workshop Associates.

Mr. Rowland has also been on the staffs of Long Island University, Brooklyn Polytechnic Institute, and Massachusetts Institute of Technology, engaged in both teaching and research.

—mwj—

(Continued on page 38)

Max. MegW/cu. in.

KU94
Kuthe Laboratories, Inc
KU 274
KU74
Kuthe Laboratories, Inc
KU93
KU73
KU72
KU70
KU92
KU71

ITT CERAMIC HYDROGEN THYRATRONS AND DIODES FOR MAXIMUM POWER/SIZE RATIO

No other hydrogen thyratron and diode line offers this wide choice of high-power types in the smallest possible tube envelopes. Made by ITT Kuthe Laboratories, most experienced maker of hydrogen-filled tubes, these ceramic thyratrons and diodes are the most complete line on the market today, with each type immediately available from production. The high-power thyratrons are designed to operate at high repetition rates and high temperatures; the high-power diodes may be used as hold-off diodes, inverse clippers and backswing clippers. Also available is an equally comprehensive line of glass thyratrons. The entire ITT hydrogen thyratron and diode program is aimed at the most demanding applications, particularly where long life and ruggedness are mandatory.

THYRATRONS	KU 70	KU 71	KU 72	KU 73	KU 74	KU 274
Performance Factor (x 10^9)	1.0	4.0	7.0	20.0	40.0	45.0
Peak Power Output, Megawatts	0.2	1.0	3.50	12.50	33.0	50.0
Forward Anode Voltage, Kilovolts	6.0	10.0	20.0	25.0	33.0	50 0
Peak Anode Current, Amperes	90	200	350	1000	2000	2000
Average Anode Current, Amperes	.100	.200	.300	1.5	4.0	4.0
Height, Inches	1.70	2.25	3.00	5.75	11.0	12.0
Diameter, Inches	1 15	1 37	1.75	3.00	4.50	4.50

DIODES	KU 92	KU 93	KU 94
Peak Inverse Voltage, Clipper, Kilovolts	25.0	33.0	33.0
Peak Forward Current, Clipper, Amperes	300	500	2000
Max. Average Current, Clipper, Amperes	.200	.500	2.0
Peak Inverse Voltage, Rectifier, Kilovolts	15.0	20.0	20.0
Peak Forward Current, Rectifier, Amperes	2.0	8.0	16.0
Max. Average Current, Rectifier, Amperes	.50	2.0	4.0
Height, Inches	3.00	6.00	8.25
Diameter, Inches	1.75	3.00	4.50

Write for information on the complete line of ITT hydrogen thyratrons and diodes. Application assistance is available for your specific requirements.

ITT

ELECTRON TUBE DEPARTMENT ■ COMPONENTS DIVISION
INTERNATIONAL TELEPHONE AND TELEGRAPH CORPORATION, CLIFTON, NEW JERSEY

ITT COMPONENTS DIVISION PRODUCTS: POWER TUBES • IATRON STORAGE TUBES • HYDROGEN THYRATRONS
TRAVELING WAVE TUBES • SELENIUM RECTIFIERS • SILICON DIODES AND RECTIFIERS • TANTALUM CAPACITORS

Circle Reader Service Card 31

Industry News

(*Continued from page 36*)

PHILCO INVESTIGATES NOVEL COMPONENTS

Investigation of novel components as applied to a high-resolution radar antenna is subject of a Philco Research Division, Blue Bell, Pa., contract in the sum of $515,107, awarded recently by Rome Air Development Center of the U. S. Air Force's Air Research and Development Command.

Department responsible for the R&D effort is Microwave and Antenna Section, under direction of Research Section Manager Murray Hoffman.

—mwj—

SUGARMAN HEADS SIGNAL ENVIRONMENT SECTION

Robert H. Sugarman has been named as head of the Signal Environment Section of AEL, Inc., Philadelphia, Pa. The Section is responsible for the analysis, measurement, and control of equipment and operational radio frequency factors which contribute to systems performance degradation.

During the past 12 years, Mr. Sugarman has been associated with the U. S. Army Signal Research and Development Laboratory at Fort Monmouth, New Jersey.

Mr. Sugarman received his BS in Electrical Engineering from Newark College of Engineering in 1945 and his MS in EE from the University of Pennsylvania in 1948.

He is a senior member of the IRE and is a member of the Armed Forces Communications and Electronic Association.

—mwj—

NEW FIRM ESTABLISHED IN FLORIDA

Systems Engineering Laboratories, Inc., Ft. Lauderdale, Fla., a new electronics research and development firm, has been established to produce data systems for defense, space exploration and industrial uses.

President and chairman of the board of SEL is William W. Dodgson, Jr., who was with the Melbourne concern for eight years, serving six years as vice president in charge of the marketing and contracts divisions.

Other SEL officers and their former positions with Radiation are: Vice President-Engineering, Perry Knight—manager, Ground Data Systems Section; Vice President A. G. Randolph—responsible for marketing of ground data systems; Secretary and Director of Contracts, Thomas J. Sullivan—legal advisor, Contracts Department; and Controller John Jackson, Jr.—assistant to the vice president-administration.

—mwj—

MOTOROLA APPOINTS WHITE

Gerald R. White has been appoint Railroad Microwave Representative Motorola Commu ications and El tronics, Inc., C cago, Ill. In th capacity, he is r sponsible for t design and sale microwave rad relay systems railroads.

White previous was Operations A ministrator for M torola's Microwave Department. As member of the department since 1955, has worked in systems and field engine ing, in research and development and microwave marketing.

White holds a MS degree in Industri Management from Loyola University Chicago and a BS in Engineering fro Loyola of the South in New Orleans. H is an associate member of both the A erican Association of Railroads and t IRE.

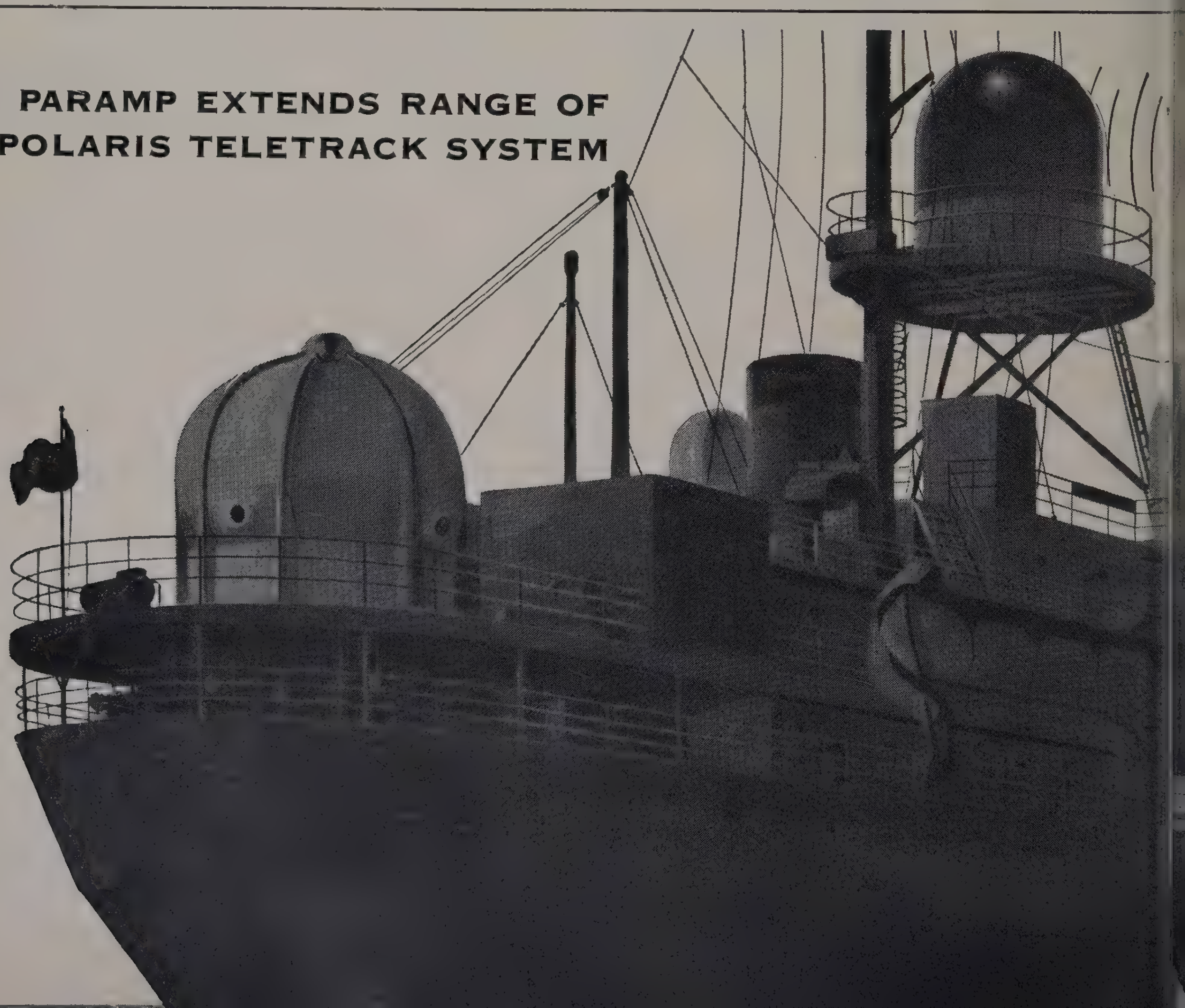
—mwj—

CORNING WILL PRODUCE RADOMES FOR TARTAR MISSILE

"Carry-on" manufacture of Pyrocera radomes for the Tartar missile has be started by Corning Glass Works, Cornin N. Y.

The company said the first producti order for Tartar radomes was complet

HUGHES PARAMP EXTENDS RANGE OF LEAR'S POLARIS TELETRACK SYSTEM



Oct. 4, 1960, the day specified by contract with Convair/Pomona, Convair Division of General Dynamics Corporation.

Tartar is a supersonic Navy ship-to-air missile produced by Convair at Pomona, Cal., for defense of the fleet against hostile aircraft. According to the Navy, the first of a new class of destroyer-type ships using Tartar is operational.

Corning was awarded the radome production contract for the Tartar missile in 1959.

Exceptional coordination in closely defining radome parameters and duplicating tolerances has been achieved by Corning and Convair/Pomona engineers, the glass firm said.

—*mwj*—

HUGHES ADOPTS NEW MICROWAVE TUBE MARKETING

The microwave tube division of Hughes Aircraft Co., Culver City, Cal., has formed two new departments and realigned its marketing organization along product lines. An operations department and a controller's office have been established and two product marketing managers have been named.

The division has been growing steadily in size and sales, Dr. Field said, and now employs approximately 450 persons. The division was established from existing company microwave tube research and production units to form a unified organization.

W. Earl Trantham, Jr. will be manager of the new operations department. His department will handle product marketing, administrative services, applications engineering and other customer service functions.

—*mwj*—

TUBE-CAVITY COMBINATION DEVELOPED BY GE

The development of a tube-cavity combination has been announced by General Electric's Receiving Tube Department, Owensboro, Ky.

A C-band tube-cavity has a metal-ceramic microwave triode as an integral part.

Main objectives of the development program, sponsored by the U. S. Army Signal Corps, are (1) to extend the upper frequency limit of microwave triodes and (2) to perfect a relatively inexpensive component for military equipment that can be replaced in the field without the need for highly trained technicians.

General Electric's developmental C-band device operates over the 5250-to-6050-megacycle frequency range with a power output of 4 to 10 milliwatts. It is designed to act as a very stable local oscillator; however, the output coupling can be increased to provide adequate power to pump a parametric amplifier.

—*mwj*—

SORGER WILL INSTRUCT AT NEW INSTITUTE

Dr. G. U. Sorger, who heads the Microwave Standards effort at Weinschel Engineering Co., Kensington, Md., has recently been appointed Assistant Professor at the new Institute of Measurement Science of the George Washington University in Washington, D.C.

The new Institute, established in February of this year in cooperation with the National Bureau of Standards and the Martin Company of Baltimore, is devoted to the study of Metrology, the science of measurements. Most faculty members are drawn from the university staff or from the National Bureau of Standards. Courses are offered in optical, thermal, and electronic measurements. Dr. Sorger, the only instructor drawn from private industry, will teach a course for graduate students in microwave measurements, including measurement of power, frequency, impedance, wavelength, and attenuation at microwave frequencies. Also included will be the study of characteristics and Q of resonant devices.

—*mwj*—

(*Continued on page 40*)

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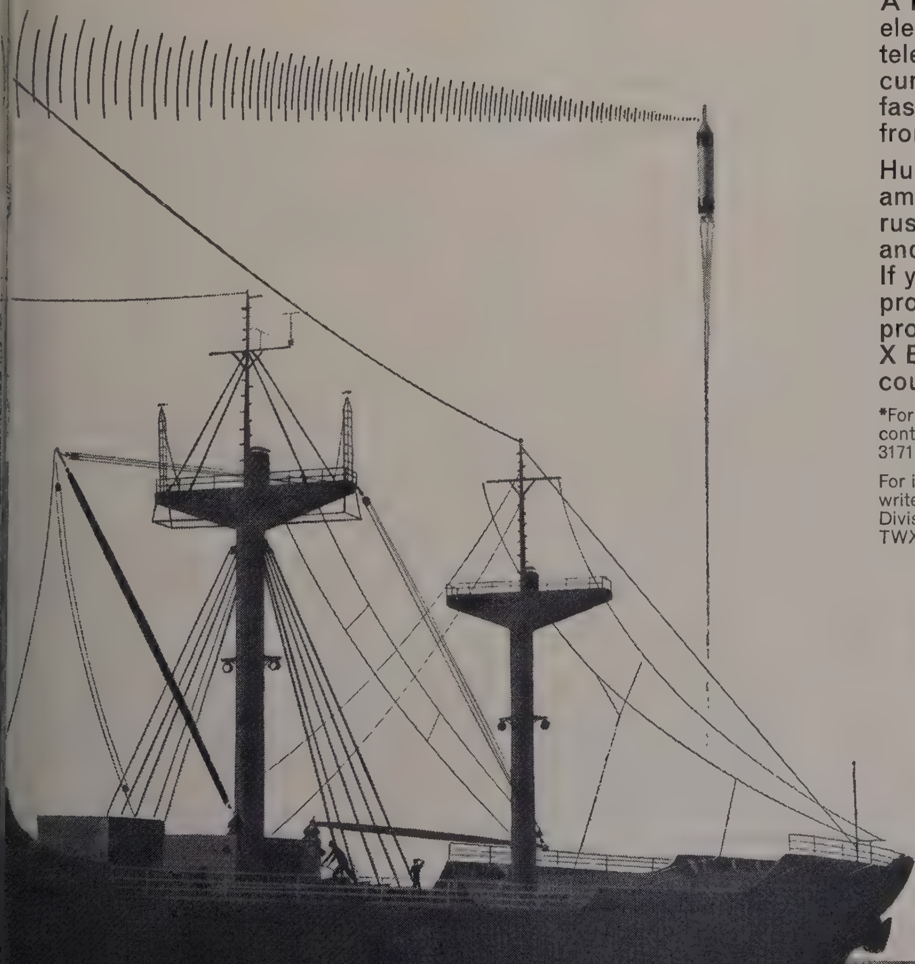
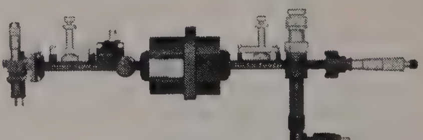


A Hughes parametric amplifier is a key element in a new *Lear Avionics Division telemetry tracking system. This system, currently under final evaluation, will enable faster and more accurate data acquisition from Polaris missiles.

Hughes delivered its first parametric amplifier to Lear 60 days ARO—received a rush order for a second unit January 16—and delivered it four days later, January 20. If you have a similar parametric amplifier problem, contact Hughes. In addition to providing "systems proven" L, S, C or X Band amplifiers, you'll get prompt, courteous and efficient service.

*For complete information regarding Lear telemetry systems contact: Manager of Marketing, Lear Astronics Division, 3171 S. Bundy Drive, Santa Monica, California.

For information regarding Hughes parametric amplifiers write, teletype or call collect: Hughes Components Division, Marketing Operations, Culver City, California. TWX-HAC SMON 7396-U. Phone UPton 0-7111, Ext. 2860.



Creating a new world with Electronics

HUGHES

HUGHES AIRCRAFT COMPANY
COMPONENTS DIVISION

COAXIAL
BROAD
BAND
FERRITE
ISOLATORS

IN SIZES FOR EVERY APPLICATION

Now—from Kearfott, a new and broader line of Ferrite Isolators to satisfy the most exacting requirements of band width and isolation. Combining low unit loss characteristics with compactness and light weight, this new series of Kearfott Coaxial Isolators is available from present stock. Immediate selection and faster delivery is assured *. . . precision performance proven.*

A FEW OF THE TYPICAL SPECIFICATIONS

MODEL	FREQUENCY	ISOLATION	INSERTION LOSS	VSWR
C991100-402	1.2—2.6 KMC	10 DB Min.	1.0 DB Max.	1.20
C992100-405	2.0—2.5 KMC	30 DB Min.	.8 DB Max.	1.20
C992100-404	2.0—4.0 KMC	10 DB Min.	1.0 DB Max.	1.20
C992100-407	3.0—3.5 KMC	35 DB Min.	.8 DB Max.	1.20
C993100-401	4.0—8.0 KMC	10 DB Min.	1.0 DB Max.	1.20
C994100-403	7.0—9.0 KMC	25 DB Min.	.8 DB Max.	1.20

Complete information on these or all of the models is available by directing inquiries to: 14844 Oxnard Street, Van Nuys, California, or the sales office in your area.

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

SALES OFFICES SEATTLE, WASH. VAN NUYS, CALIF. PHOENIX, ARIZ. DAYTON, OHIO CLIFTON, N.J.
PALO ALTO, CALIF. SAN DIEGO, CALIF. DALLAS, TEX. CHICAGO, ILL. WASHINGTON, D.C.

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Industry News

(*Continued from page 39*)

TRW FORMS MICROWAVE DIVISIO

Formation of the TRW Microwave D
vision, within the TRW Componen
Company, and simultaneous transfer
the activities and personnel of this div
sion from Cleveland, Ohio to Thomps
Ramo Wooldridge headquarters in Ca
oga Park, Cal., were announced today
Warren B. Hayes, TRW Vice Presid
and General Manager of TRW Compo
ents Company.

Spun-off from the TRW Tapco Grou
the Microwave Division was transferr
to the San Fernando Valley complex
part of an overall corporate plan to co
solidate and increase activities of relate
company elements.

The Microwave Division will cons
initially of 50 microwave personnel,
which 7 are key engineers, relocated fro
Cleveland. It is expected that this figu
will increase over the next year to mo
than 100. The division will continue
conduct research and development
new product lines in addition to the cu
rent work on switches, filters, antenna
and connectors.

—*mwj*—

WANTUCH ELECTED
VICE PRESIDENT AT AIRTRON

Dr. Ernest Wantuch, director of th
Advanced Devices Laboratory of Airtro
a division of Litton Industries, Morr
Plains, N. J., has been elected a vi
president of the division, it was announc
by William F. Boyd, Airtron vice pres
dent and general manager.

Dr. Wantuch has been associated wi
Airtron since 1956, when he joined Ai
tron as head of the Cambridge Divisi
which was formed to study and devel
advanced microwave ferrite devices.

In his present position, Dr. Wantuch
responsible for the direction of all A
vanced Devices Laboratory activities,
well as for the expansion of the sco
of the laboratory to include new areas
study and development.

—*mwj*—

RAYTHEON PLANS
RADAR TRANSMITTER

A five million-watt radar transmitt
to provide long-range tracking of spac
probes and orbital vehicles is under d
velopment by Raytheon Company, Lexin
ton, Mass.

The transmitter will be a major part
a radar system with a 60-foot diamet
dish antenna to be used by the Nation
Aeronautics and Space Administration
Wallops Island, Va. The system will als
be used to measure the radar cross sectio
of space vehicles to determine their suit
bility for communication or navigatio
applications.

Work on the transmitter is being pe
formed by Surface Radar and Navigatio
Operations of Raytheon at Waylan
Mass.

—*mwj*—

KENT ELECTED VICE PRESIDENT ENGINEERING

Leonard I. Kent was elected Vice President-Engineering and a member of the Board of Directors of Microwave Semiconductor & Instruments Inc., Richmond Hill, N. Y. MSI, which was recently formed to enter the field of microwave components and equipments, leased 6200 sq. ft. in the Richmond Hill section of Queens, N. Y.

Mr. Kent comes to MSI with experience in microwave electronics, most recently as Director of Engineering with Narda Microwave Corp. He joined Narda in 1957 as Chief Microwave Engineer, where he directed and participated in the design and development of all types of microwave instrumentation and equipment from 20 to 90,000 Mc. Programs initiated under his direction included the standardization of Ridged Waveguides in conjunction with the Electronics Industries Association and the U. S. Signal Corps. Also under his direction and initiated by Mr. Kent was the Microwave Electronics Group and the High Power Electronics Division.

Mr. Kent is a graduate of The Cooper Union School of Engineering, where he received a BEE. He has also been awarded an MEE and is currently completing his requirement for the DEE at the Polytechnic Institute of Brooklyn. He has written several papers on directional couplers, power measuring devices and ridged waveguides.

—mwj—

UNIT CUTS JET'S RADAR TEST TIME

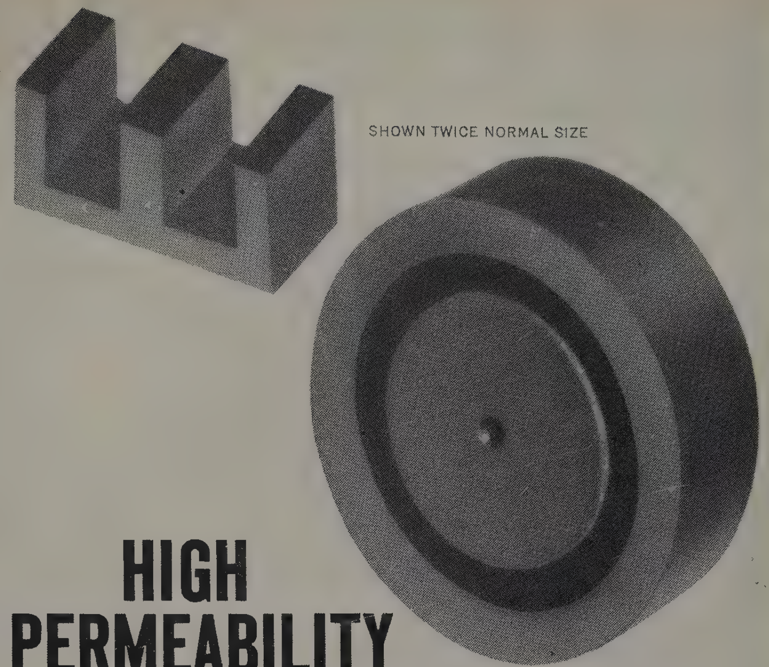
Inflight performance of airborne radar units built into the Air Force's supersonic F-105D fighter-bomber can now be checked out on the ground in one third the time generally required, Republic Aviation Corp., Farmingdale, L. I. has reported.

The first model of a "flightline" radar testing system that will check the jet's radar in all of its various modes — Air-to-air, air-to-ground, terrain avoidance, and others — has been received here. Up until now, said company engineers, there has been no single piece of equipment to do an over-all radar test job. This has meant loss of time, moving the aircraft from one location to another for separate testing of each of the different modes. A complete checkout has previously required 24 hours.

The "RTS-103" test unit was developed according to Republic's specifications by Remanco, Inc. of California. The system is mounted on a truck for maneuverability. It requires no physical connections with the aircraft during the radar tests.

—mwj—

(*Continued on page 44*)



HIGH PERMEABILITY FERRITE

Kearfott's MN-30 ferrite is a highly machinable, high-permeability ferrite for use in magnetic cores. Its low losses and high saturation magnetization permit efficient application at frequencies up to 500 kc, while eddy current losses are minimal due to the material's high resistivity. Custom shapes and sizes available with dimensional tolerances within ± .001, density ranges from 4.9 to 5.0 gm/cm³. High quality and uniformity are assured through special compounding techniques, automatic control of firing, and rigid quality control.

TYPICAL CHARACTERISTICS

Initial Permeability at 21°C and 5 kc	3000 Min.
Maximum Permeability, measured at 2000 gauss	6000
Flux density at 7 oersteds, using Rowland Ring Test Circuit and Fluxmeter	4600 gauss
Flux Excursion for 1 oersted	3500 gauss
Retentivity (B_r)	1300 gauss
Coercivity (H_c)	0.13 oersteds
Loss Factor 1 μ Q at 50 kc	7.5×10^{-6}
Loss Factor 1 μ Q at 500 kc	30×10^{-6}
Temperature Coefficients of initial permeability (% per °C):	
From —30°C to +125°C	0.28
Curie Temperature	over 180°C
D. C. Restivity	250 ohm-cm

(All magnetic properties are held within a tolerance of ±15%)

Write for complete data

KEARFOTT DIVISION
GENERAL PRECISION, INC.

Little Falls, New Jersey

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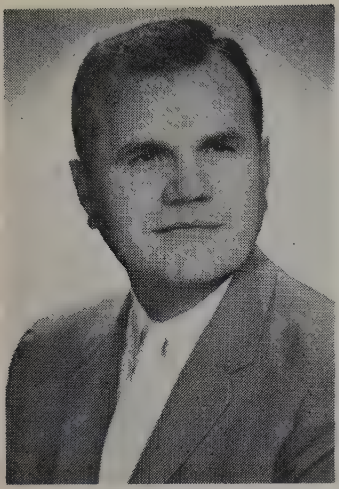


" . . . IT IS NOW NEARLY IMPOSSIBLE TO IDENTIFY A SPECIFIC SIZE OF WAVEGUIDE BY THE LETTER DESIGNATION . . . "

waveguide alphabet soup or KXCSLP

TORE N. ANDERSON, ASSOCIATE, *the microwave journal*

During the war, frequency assignments were classified for specific military assignments and, as our friend David Andrews explained in the guest editorial in the November issue of *the microwave journal*, coded letter designations were used for each of the frequency bands.

Many of these designations are still in common use today, despite the effort of military people to officially obsolete all of these frequency codes. The most used alphabetical designations are S, X and K, generally meaning devices operating around 3,000, 10,000 and 24,000 megacycles and using waveguides of 3 x 1 1/2, 1 x 1/2 and 1/2 x 1/4 O.D. respectively.

The military waveguide nomenclature system assigned RG/U numbers to each specific waveguide construction and dimensions, so that there are several choices of RG numbers to fit a given frequency range. In the early days this was quite satisfactory in that there were relatively few sizes of waveguides involved to fit the majority of the microwave applications then in vogue. With the build-up of the microwave industry, several of the test equipment manufacturers began assigning additional alphabetical designations for ready reference in their own catalogs, to those already in common usage. This has progressed to a point where it is now nearly impossible to identify a specific size of waveguide by the letter designation; since no two manufacturers have chosen to agree, the microwave industry is caught in a "Waveguide Alphabet Soup".

Shortly after the war EIA developed a standard for rectangular waveguides (TR108) and a nomenclature system which was consistent with the waveguide size and makes for ready identification. This was to use the WR standing for waveguide rectangular and two digits standing for the first two digits of the broad dimension expressed in hundredths of an inch. For example:

WR-90 indicates .900″ x .400″ waveguide or the common X-band waveguide, for which the military use RG-52/U, RG-67/U and RG-? /U for the brass, alum num and magnesium version of this waveguide, respe tively.

WR-132, which is a popular waveguide size for commercial microwave relay systems, is variously known a J-band and C-band and/or X_B band, and to resolve customer's inquiry generally is a several minute discussio back and forth as to the exact terminology involved.

It is mandatory, therefore, to eliminate the alphabe soup from the microwave industry and stay with the EI commercial designations for these waveguide dimension in all references; although perhaps a little more cumbe some than the alphabetical system, it is certainly le confusing.

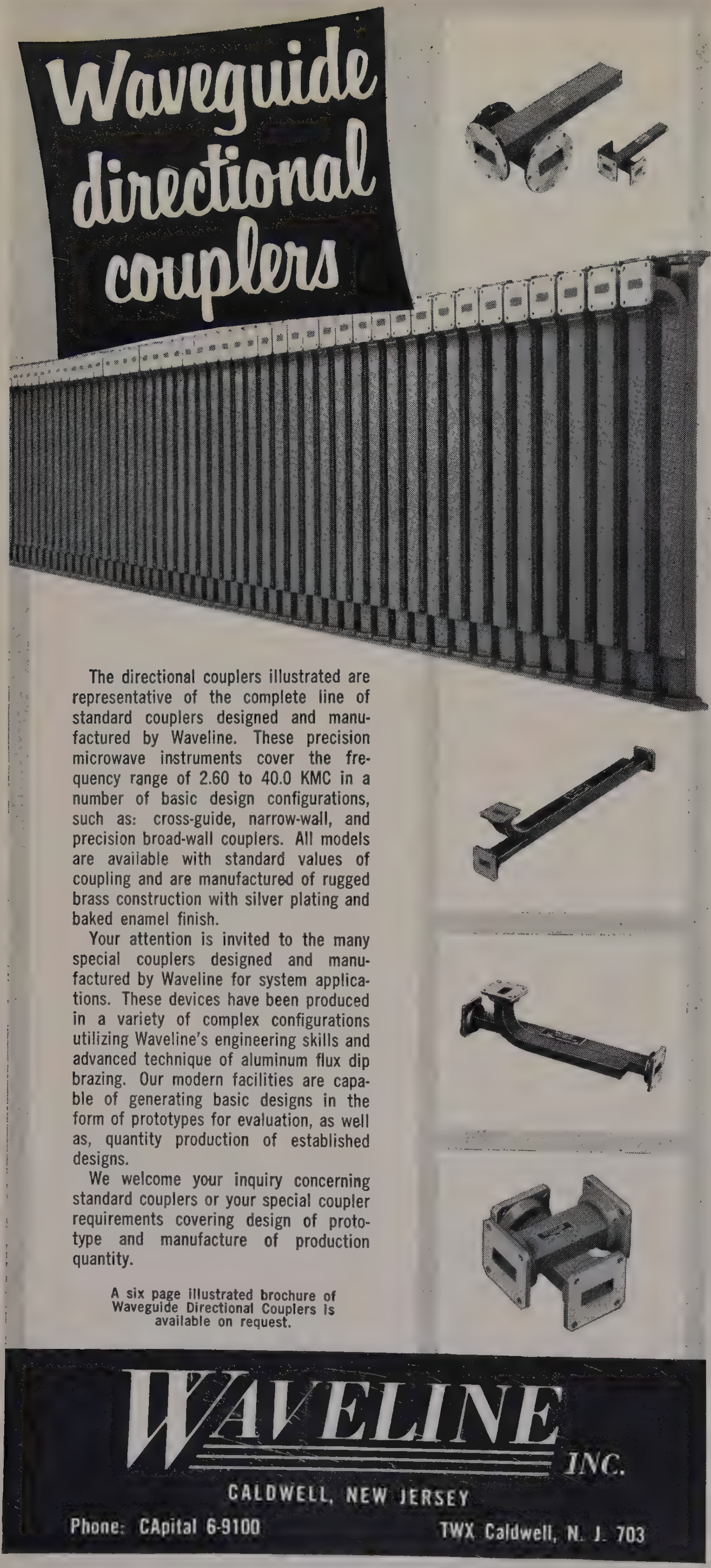
Rectangular waveguide sizes from 23.0 inches by 11 1 inches (WR-2300) down to .1051 x .0255 (WR-5) an in common usage with extensions to this table to b expected as time goes on.

The International Electrotechnical Commission ha devised a frequency dependent numbering scheme fo these waveguides because of the problem of inch versu the metric system. For example, IEC R100 is our WR-9 or X-band waveguide, and stands for ten times the nom nal center frequency in gigacycles/second.

A complete tabulation of waveguide dimensions, fr quency range, EIA designations, IEC number, U. S. mil tary nomenclature, and various commercial alphabetica assignments is given with this essay. It is time to eliminat the confusion in waveguide designations and be specifi Use the EIA nomenclature!

E I A* DESIG-NATION	WAVE-GUIDE I.D., INCHES	FRE-QUENCY RANGE* IN G $^{c}/_{s}$	MILITARY NOMENCLATURE	I E C DESIG-NATION	COMMERCIAL ASSIGNMENT			
					F X R	Hewlett Packard	Narda	Sperry Microline
WR 2300	23.00 x 11.50	.31 TO .43		R 3				
WR 2100	21.00 x 10.50	.31 TO .68		R 4	J			
WR 1800	18.00 x 9.00	.39 TO .79	RG-201/U ALUMINUM	R 5				
WR 1500	15.00 x 7.50	.47 TO .75	RG-202/U ALUMINUM	R 6				
WR 1150	11.50 x 5.75	.64 TO .96	RG-203/U ALUMINUM	R 8				
WR 975	9.75 x 4.875	.75 TO 1.12	RG-204/U ALUMINUM	R 9				
WR 770	7.70 x 3.85	.96 TO 1.45	RG-205/U ALUMINUM	R 12				
WR 650	6.50 x 3.25	1.12 TO 1.70	RG-69/U COPPER RG-103/U ALUMINUM	R 14	L		L	L
WR 510	5.10 x 2.55	1.45 TO 2.20		R 18				
WR 430	4.30 x 2.15	1.70 TO 2.60	RG-104/U COPPER RG-105/U ALUMINUM	R 22	R		LS	
WR 340	3.40 x 1.70	2.20 TO 3.40	RG-112/U COPPER RG-113/U ALUMINUM	R 26				
WR 284	2.840 x 1.340	2.60 TO 3.95	RG-48/U COPPER RG-75/U ALUMINUM RG-167/U MAGNESIUM	R 32	S	S	S	S
WR 229	2.290 x 1.145	3.30 TO 4.90		R 40				
WR 187	1.872 x .872	3.95 TO 5.85	RG-49/U COPPER RG-95/U ALUMINUM RG-168/U MAGNESIUM	R 48	H	G	C	C
WR 159	1.590 x .795	4.90 TO 7.05		R 58		C		
WR 137	1.372 x .622	5.85 TO 8.20	RG-50/U COPPER RG-106/U ALUMINUM RG-169/U MAGNESIUM	R 70	C	J	XN	G
WR 112	1.122 x .497	7.05 TO 10.0	RG-51/U COPPER RG-68/U ALUMINUM RG-170/U MAGNESIUM	R 84	W	H	XB	H
WR 90	.900 x .400	8.20 TO 12.4	RG-52/U COPPER RG-67/U ALUMINUM RG-171/U MAGNESIUM	R 100	X	X	X	X
WR 75	.750 x .375	10.0 TO 15.0		R 120		M		
WR 62	.622 x .311	12.4 TO 18.0	RG-91/U COPPER RG-107/U SILVER RG-172/U MAGNESIUM	R 140	Y	P	KU	U
WR 51	.510 x .255	15.0 TO 22.0		R 180				
WR 42	.420 x .170	18.0 TO 26.6	RG-53/U COPPER RG-66/U SILVER RG-121/U ALUMINUM RG-173/U MAGNESIUM	R 220	K	K	K	
WR 34	.340 x .170	22.0 TO 33.0		R 260				
WR 28	.280 x .140	26.5 TO 40.0	RG-96/U SILVER	R 320	U	R	V	
WR 22	.224 x .112	33.0 TO 50.0	RG-97/U SILVER	R 400	Q		O	
WR 19	.188 x .094	40.0 TO 60.0		R 500				
WR 15	.148 x .074	50.0 TO 75.0	RG-98/U SILVER	R 620	M		M	
WR 12	.122 x .061	60.0 TO 90.0	RG-99/U SILVER	R 740	E		E	
WR 10	.100 x .050	75.0 TO 110.0		R 900				
WR 8	.080 x .040	90 TO 140	RG-138/U SILVER	R 1200	F		N	
WR 7	.065 x .0325	110 TO 170	RG-136/U SILVER	R 1400				
WR 5	.051 x .0255	140 TO 220	RG-135/U SILVER	R 1800	G		A	
WR 4	.043 x .0215	170 TO 260	RG-137/U SILVER	R 2200				
WR 3	.034 x .017	220 TO 325	RG-139/U SILVER	R 2800			R	

* *PREFERRED DESIGNATION: WR——— OR FREQUENCY RANGE.*



Waveguide directional couplers

The directional couplers illustrated are representative of the complete line of standard couplers designed and manufactured by Waveline. These precision microwave instruments cover the frequency range of 2.60 to 40.0 KMC in a number of basic design configurations, such as: cross-guide, narrow-wall, and precision broad-wall couplers. All models are available with standard values of coupling and are manufactured of rugged brass construction with silver plating and baked enamel finish.

Your attention is invited to the many special couplers designed and manufactured by Waveline for system applications. These devices have been produced in a variety of complex configurations utilizing Waveline's engineering skills and advanced technique of aluminum flux dip brazing. Our modern facilities are capable of generating basic designs in the form of prototypes for evaluation, as well as, quantity production of established designs.

We welcome your inquiry concerning standard couplers or your special coupler requirements covering design of prototype and manufacture of production quantity.

A six page illustrated brochure of Waveguide Directional Couplers is available on request.

WAVELINE INC.

CALDWELL, NEW JERSEY

Phone: CApital 6-9100 TWX Caldwell, N. J. 703

Circle Reader Service Card 35

Industry News

(*Continued from page 41*)

WHITE HOUSE SCIENCE AIDE RECEIVES EIA MEDAL

Dr. Jerome B. Wiesner, a special assi tant to President Kennedy for science an technology, was named by the Electron Industries Association board of directo for award of the 1961 EIA Medal of Ho or for "distinguished service contributin to the advancement of the electron industry".

Dr. Wiesner is the first governme official to be selected for the award sin its establishment in 1952. Presentation the medal is to be made at the assoc tion's annual convention in Chicago May.

Dr. Wiesner is now on leave as direct of the Research Laboratory of Electroni at the Massachusetts Institute of Tec nology and was, until his appointme to the White House post, a director the Sprague Electric Co.

Dr. Wiesner was chairman of the stee ing committee of the Center for Co munication Sciences established at M.I. in 1958 to study both man-made and na ural communication systems. He also ha been active in advancement of technolog related to the nation's international pro lems both as a member of the President Science Advisory Committee and of th committee which prepared the Gaither r port. He also was staff director of th United States delegation to the 1958 Ge eva conference on the prevention of su prise attack.

— *mwj* —

AIR FORCE AWARDS CONTRACT T AVCO-EVERETT

Basic research in magnetohydrodynam (MHD) will be extended under a ne $298,410 contract awarded to the Avc Everett Research Laboratory, Everet Mass., by the Air Force Office of Scienti Research, it has been announced.

Magnetohydrodynamics, the study of plasma—high temperature, highly ionize gas—interacted with a magnetic field, h been under investigation at the Evere laboratory for more than five years.

The contract, to run for a year, calls fo theoretical and experimental study MHD principles. Special attention wi be given to the behavior of the magnet field in a plasma, the radiation emitte by the plasma, and the electrical condu tivity of the plasma.

These studies will provide a bett understanding of the underlying principl of MHD and will play an important ro in the application of MHD to space fligh and power generation and may define ne areas of application.

A large magnetic annular shock tu (MAST), developed especially for th project, will be used as a primary researc tool.

— *mwj* —

(*Continued on page 46*)

PROGRESS IN MICROWAVES

NEW X-BAND TUBES IMPROVE MICROWAVE RECEIVER PERFORMANCE

for Radar, Communications, ECM, Radiometry, Radio Astronomy Systems

The latest advances in G.E.'s continuing program for providing complete microwave coverage in a wide variety of tubes from L to K band are the traveling-wave tubes and voltage-tunable magnetron shown on the right.

OUTSTANDING LOW-NOISE, HIGH-GAIN PERFORMANCE

TWT types Z-3103 and Z-5259 are particularly suited for use in X-band receiver systems as broad-band amplifiers. The low-noise characteristics, ranging from 7 to 10 db max., coupled with a uniform high minimum gain of 25 db, make possible new levels of performance in detection and amplification of weak signals.

The low saturation power of both tubes protects mixers and other components from overload damage. Permanent magnet focusing eliminates need for additional power supply equipment in the circuit, including weighty, space-consuming solenoids.

Because of their inherent broad-band operation, the tubes require no tuning over their respective ranges, thereby permitting a significant degree of flexibility in frequency selection.

Compact and rugged, these metal-ceramic tubes are completely packaged with r-f and d-c connectors. The tubes illustrated withstand stringent specifications for shock (50 G's) and vibration (15 G's) in critical military applications.

VTM'S PROVIDE LINEAR TUNING

Newest addition to a growing line of G-E Voltage-tunable Magnetrons is the Z-5429. This tube's broad-band frequency range suits its use as a local oscillator in radar receiver circuits. A complete r-f power package, the tube gives a minimum of one milliwatt of linearly voltage-tuned power over the entire X-band range, without mechanical adjustment.

FREQUENCY RANGES AVAILABLE* TO DATE

Band	VTM (Kmc)	TWT (Kmc)
K	—	35.0–40.0 14.0–18.0
X	8.5–11.0	7.0–12.0
C	—	4.0–8.0
S	2.2–3.85	—
L	1.0–2.3	—

**This spectrum readily broadened and adapted for YOUR specific applications.*

TO ORDER, or to obtain more information, contact your nearest Power Tube sales office (telephone numbers listed below). 265-04-9545-8481-34

POWER TUBE DEPARTMENT

GENERAL ELECTRIC

TELEPHONE TODAY—*Syracuse, OL 2-5102 . . . Clifton, N.J., GR 3-6387 . . . Washington, D.C., EX 3-3600 . . . Chicago, SP 7-1600 . . . Dayton, BA 3-7151 . . . Los Angeles, GR 9-7765.*

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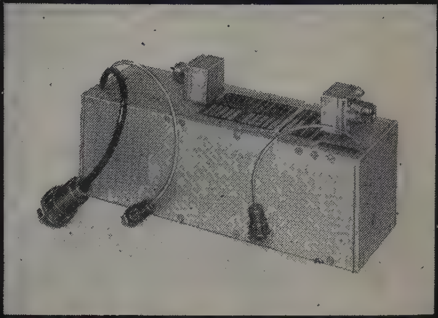
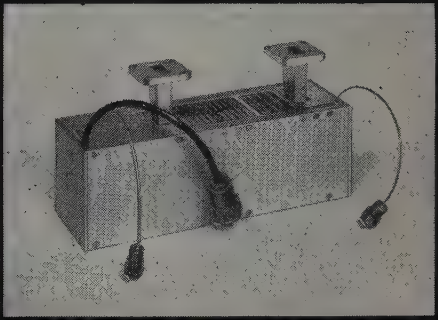
NEW TRAVELING WAVE TUBES

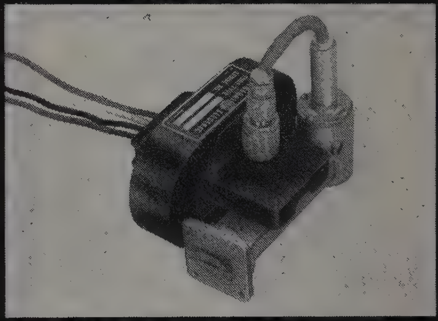


Z-3103 7.0-11.0 Kmc, 5 mw Output, 10 db Max. Noise Figure



Z-5259 8.0-12.0 Kmc, 5 mw Output, 10 db Max. Noise Figure

NEW VOLTAGE TUNABLE MAGNETRON



Z-5429 8.5-11.0 Kmc, 1 mw Output (min.), 9.0 mc/v Tuning Rate

G-E POWER TUBE DEPARTMENT PRODUCTS ALSO INCLUDE:

- Ignitrons
- Hydrogen Thyratrons
- Magnetrons
- Metal-ceramic tetrodes
- High-power duplexers
- High-power waveguide filters
- Klystrons
- Thermionic Converters

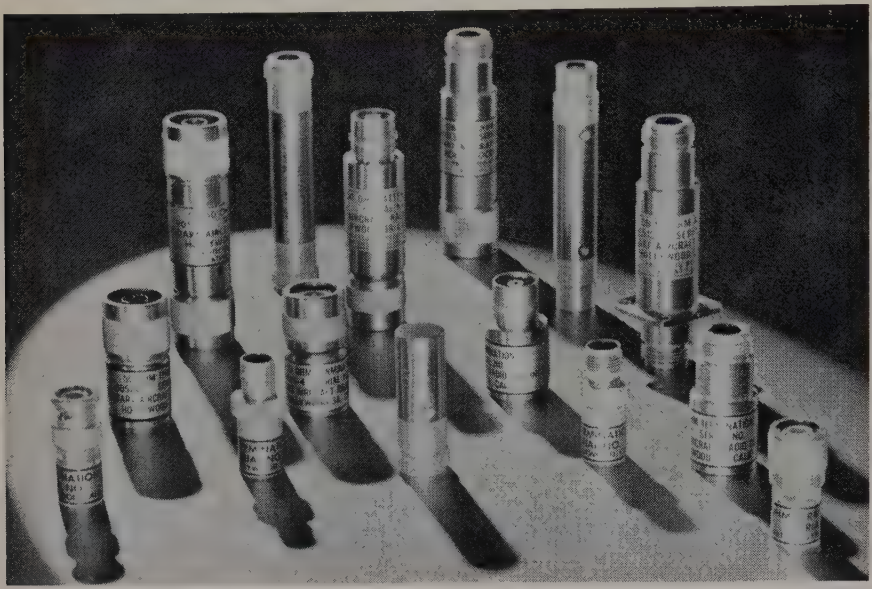
from Stoddart's selection of more than

7800 UHF attenuators

you can have

off-the-shelf delivery

of all common db values and types



... and as an additional service, Stoddart now furnishes Certified Inspection Test Reports at no extra charge with every order pertaining to government contracts.

Stoddart attenuators* provide highly accurate and stable operation over the frequency range of dc thru 3000 mc and are available in any value, including fractional values, from 0 db thru 60 db in any conceivable combination of Types N and C connectors, and a wide variety with flanges for panel mounting. 50-ohm terminations, dc thru 7000 mc, and 70-ohm terminations, dc thru 3000 mc are also available.

Stoddart's new turret attenuators*, 2, 6 and 10-position, offer quick change of db combinations compatible to your system requirements.

**Patent applied for*

Send for 16-page catalog No. AT-3

SEE OUR SPECIFICATIONS IN V·S·M·F THE MICROFILM CATALOG FILE

STODDART
AIRCRAFT RADIO CO., INC.
6644 Santa Monica Blvd., Hollywood 38, Calif. HO 4-9292
serving 33 countries in radio interference control

Circle Reader Service Card 37

Industry News

(*Continued from page 44*)

MERRILL NAMED TO NEW POST AT HARRIS-INTERTYPE

Harris-Intertype Corp., Cleveland, Ohi has elected Grayson Merrill, 49-year-ol scientist-administrator, to the new corporate post of vice president — electronics. Merrill, a former U.S. Navy captain and first technical director of the Navy's "Polaris" program, has resigned as general manager of the Astrionics Division of Fairchild Engine and Airplane Corp., Long Island, N. Y.

Merrill will have corporate responsibility for the company's two electronics divisions—PRD Electronics, Inc., Brooklyn and Gates Radio Co., Quincy, Ill., producers of microwave and broadcasting equipment respectively.

From 1952 to 1955 he was director o the Naval Aeronautical Electronics Laboratory, Johnsville, Pa., developing and testing communications equipment, radio navigation devices and advanced radar systems. He headed the system studies leading to development of the submarine launched "Polaris" missile in its present form. At Fairchild he was in charge o engineering and production of guidance and control systems, data links, radar systems, check-out equipment and related electronic products for use with aircraft surveillance drones and space craft.

— *mwj* —

WARNER JOINS MAGNION AS GENERAL MANAGER

Caleb Warner has joined the growing staff at Magnion, Inc., Cambridge, Mass. as General Manager. During the past nine years Mr Warner has been with the Arthur D Little, Inc., in various management and engineering capacities.

He was responsible in recent years for development and promotion o proprietary research equipment manufactured by ADL, including their high and low temperature apparatus and scientific magnets.

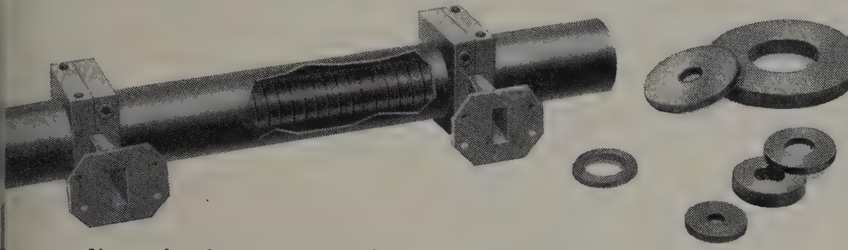
At Magnion he will have charge o proprietary development as well as contract research in the company's Plasmaflux and Uniflux lines of magnets for general laboratory use, MHD work, plasma studies, energy conversion and ion beam focusing and bending. He will also head the high field pulsed magnet work and development in superconducting magnets.

— *mwj* —

(*Continued on page 48*)

INDOX I and INDOX VI Permanent Magnets

Make Possible Simple, More Compact TWT Design



If your line of microwave equipment includes traveling wave tubes, you will be interested in Indiana Steel's amazing ceramic permanent magnets called INDOX.

Unlike heavy Alnico materials, INDOX offers designers of microwave equipment a new, light, inexpensive and easy-to-assemble permanent magnet in the sizes, shapes and strengths necessary for today's critical applications.

For example, in periodic focusing traveling wave tubes, INDOX can supply a much higher flux density due to its higher intrinsic coercive force. And INDOX pieces may also be magnetized prior to assembly without appreciable loss of flux density.

Not only does INDOX open new doors of design, but Indiana Steel now offers two grades of INDOX to meet special microwave design problems—INDOX I and INDOX VI.

INDOX I

In addition to having a higher intrinsic coercive force than Alnico, INDOX I is an inexpensive material manufactured to design specifications at moderate die cost. Irreversible flux density losses do not occur until very low operating temperatures are reached. And INDOX I produces a greater flux density than many other materials when operating low on the demagnetization curve. (See curve below.)

INDOX VI

Through extensive research in Indiana's R&D laboratories, a new, more powerful INDOX material has now been released for use in microwave equipment, particularly the TWT's. Having a greater energy product, INDOX VI can be used when a greater flux density is required or when a smaller magnet must be used.

AVAILABLE FROM STOCK NOW!

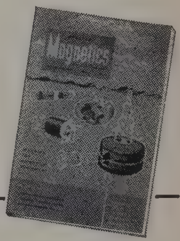
Many unground sizes of INDOX I and VI magnets are now in stock. If required, magnets may be ground to closer tolerance prior to assembly. Magnets may be magnetized before or after shipment, as desired.

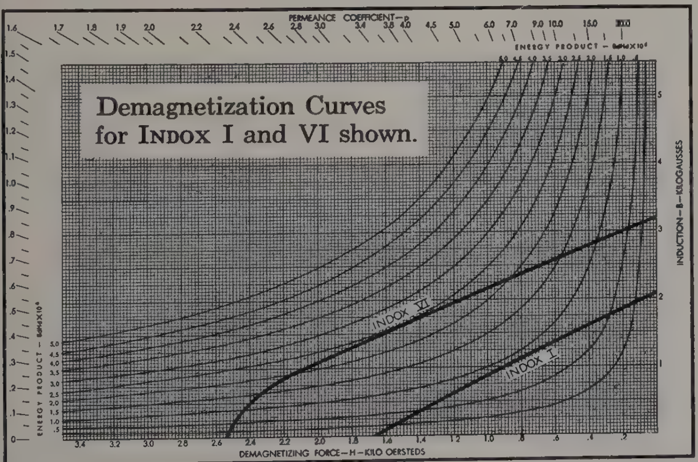
DESIGN ENGINEERING NOTE:

Indiana manufactures the widest selection of permanent magnet materials, available in thousands of sizes and shapes. Therefore, you can depend upon Indiana to give unbiased advice in choosing the correct magnet material for your application.

What are your permanent magnet requirements in the broad-band microwave field? It's likely an experienced Indiana application engineer can help you, so write for full information. Request Bulletin 18Q5 (INDOX I and V) and Bulletin 353Q5 (INDOX VI).

NEW! *Recently published data on predicting effect of low temperature on* INDOX V *and* VI, *compiled by Indiana scientists. For your copy, write for Applied Magnetics, Fourth Quarter, 1959.*




Demagnetization Curves for INDOX I and VI shown.

TYPICAL CHARACTERISTICS

	INDOX I	INDOX VI
Coercive Force (H_c) oersteds - - - - -	1,825	2,550
Residual Induction (B_r) gausses - - -	2,200	3,200
Peak Energy Product (B_dH_d) - -	1.0×10^6	2.4×10^6
Reversible Permeability -	1.2	1.06
Temperature Coefficient - - - -	−0.19%/°C	−0.19%/°C
Magnetization Field for Saturation, oersteds -	10,000	10,000
Chemical Composition -	$BaFe_{12}O_{19}$	$BaFe_{12}O_{19}$
Specific Gravity - - -	4.7 or 0.17 lb/cu in	4.5 or 0.162 lb/cu in

INDIANA STEEL PRODUCTS
Division of Indiana General Corporation
Valparaiso, Indiana

In Canada: The Indiana Steel Products Company of Canada Limited, Kitchener, Ontario

INDIANA PERMANENT MAGNETS

112

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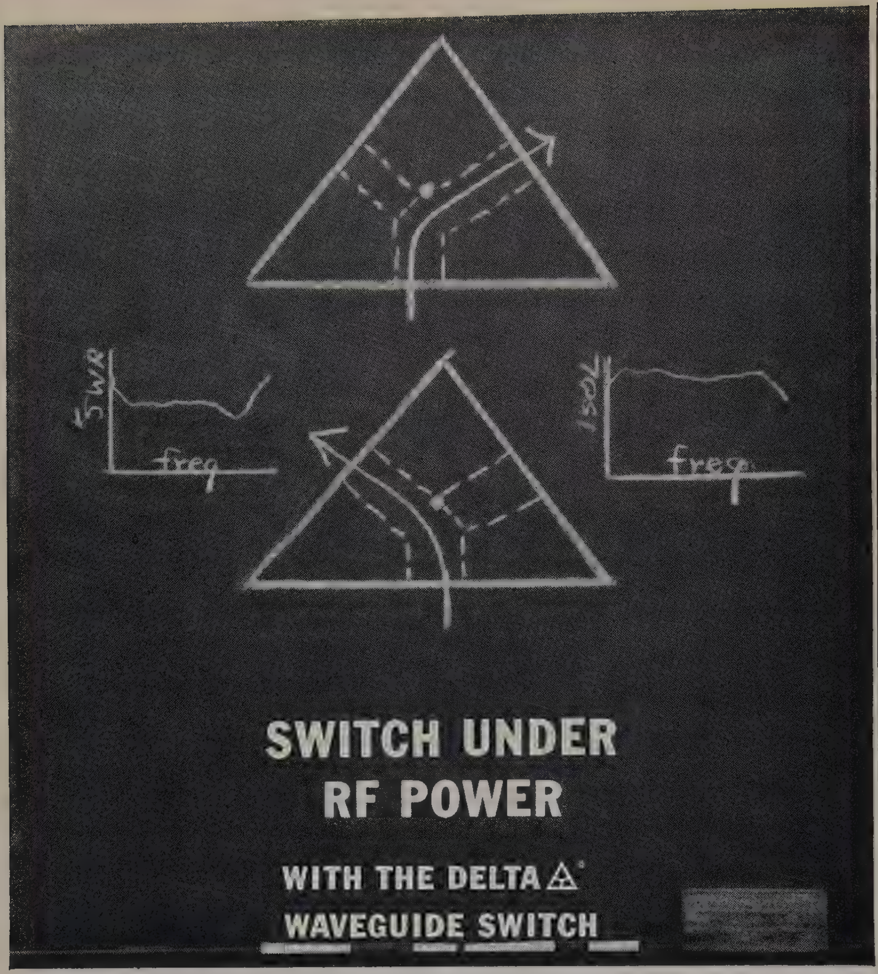


7 milliseconds switching time
7 ounces for x-band model
Operates in severe environments

A new concept in remotely-controlled microwave switching, DELTA △ Waveguide Switches permit 7 millisecond switching under rf power. Control circuitry to shut down magnetrons or other power sources may be *eliminated* in many systems. Switching under rf power is possible because the switching element is a thin metal vane which acts as a power divider during the switching cycle. The benefits—LIGHT WEIGHT, RELIABLE OPERATION and MINIMUM ACTUATOR POWER.

The DELTA △ W-6XA shown here is one of a complete line of rugged waveguide switches designed for reliable operation in critical environments. Write or call us or your Don-Lan Engineering Representative for complete specifications on these switches today.

actual size
(x-band)

Don-Lan Electronics, Inc.
a subsidiary of
Quantatron, Inc.
1131 Olympic Blvd.
Santa Monica, California
EX 3-0758

*PATENT PENDING

Don-Lan specializes in combining optimum microwave and electro-mechanical techniques. Consult us on your microwave electronic problems.

Circle Reader Service Card 39

Industry News

(*Continued from page 46*)

RADIO INTERFERENCE SYMPOSIUM SCHEDULED BY IRE

The Third National Symposiu sponsored by the IRE Professional Grou on Radio Frequency Interference (PGRF will be held in Washington, D.C. c June 12 and 13.

The technical sessions will be of spec interest this year because of the time theme: "What are the data required f interference prediction and control a how are these data to be obtained?" Th fits in closely with the Department of D fense Collection Plan for Equipment Spe trum Signatures.

Unintentional interference manifes itself in a number of ways. Certain mi air aircraft collisions, inadvertant missi explosions, and interruption to voice an television communications are a result this culprit at work. When coupled wit international jamming, interference ca make much of a nation's electronics d fense system ineffective unless suitab measures are taken.

Until recent years the problem of radi frequency interference (RFI) has not r ceived a great deal of attention. Less tha three years ago the IRE formed its 28t professional group in recognition of th increasing interest in RFI. Finally, la year the Department of Defense initiate the Electromagnetic Compatability Pr gram to cope with the problem on a larg scale and it is now putting emergen funds to work.

Toward these and related governme and industrial interests, the IRE is spo soring its symposium. Last year's turno was up 60 per cent over the previous ye and more than 600 are expected to a tend this year. Each of the main sessio will include panel discussions by autho ties in their respective fields.

—*mwj*—

HEROLD APPOINTED TO PLANNING POST AT SANDERS

Sanders Associates, Inc., Nashua, N. H has appointed Erich A. Herold to th position of Manager of Manufacturin Planning, according to Royden C. Sander Jr., president.

Mr. Herold joins Sanders after havin been employed by Republic Aviatio Farmingdale, N. Y., for the past 21 year During the last two years he was assista factory manager at Republic. In his ne position, Mr. Herold will be responsib for long range manufacturing plannin as it pertains to facilities, manpower, an general operation schedules.

A graduate of Cooper Union Institu of Technology, New York city, in 194 where he earned his degree in mechanic engineering, Mr. Herold earned his ele trical engineering degree at Bliss Electr cal College, Tacome Park, Md.

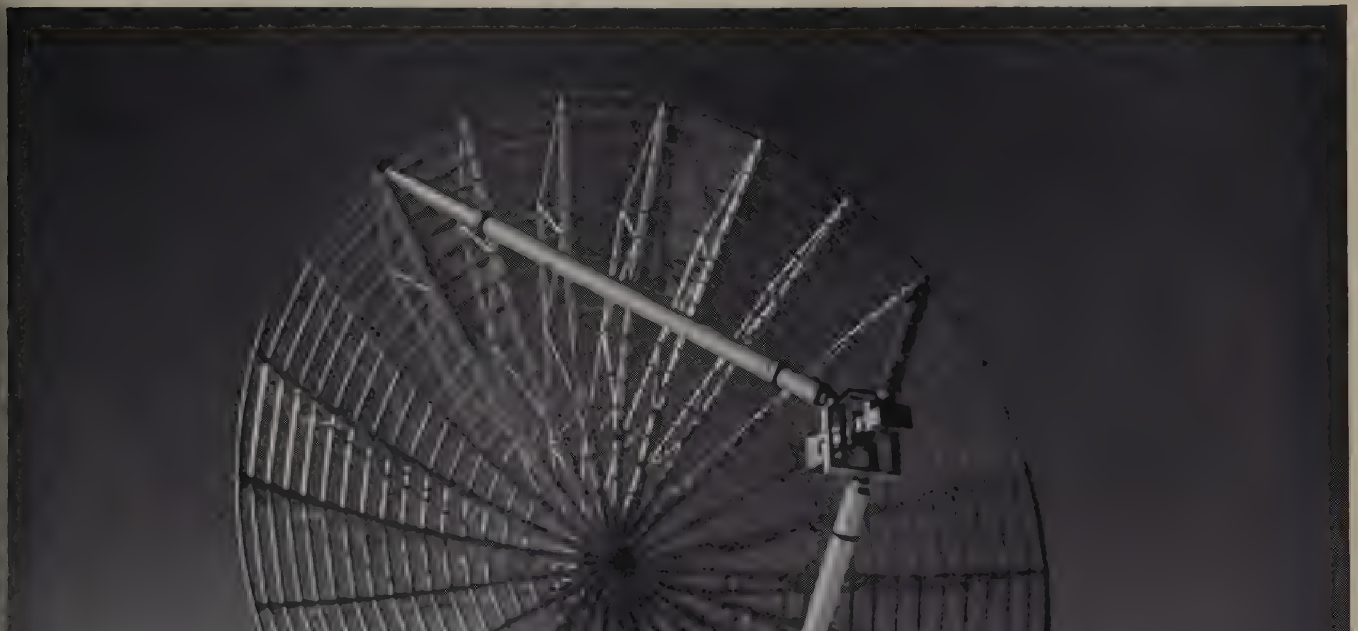
—*mwj*—

(*Continued on page 50*)

The antenna completely packed and ready for transit.

The antenna assembled but not erected.

The antenna partially erected.



ASI!

30-foot MOBILE ANTENNA offers the solution to tactical communication problems . . . This is the new Model 111 — a 30′ mobile scatter antenna by Antenna Systems, Inc. designed for tactical applications in scatter links.

In transit, this lightweight, self-contained unit, complete with 30′ mesh reflector, torque tube support, and all associated hardware nests snugly and securely on a steel flat bed trailer. On location, the antenna can be rapidly assembled. A winch or a hydraulic lifting device, mounted on the trailer, provides for quick erection into operating position.

ASI is fully capable of modifying this mobile and versatile package to meet individual requirements . . . to support smaller or larger antennas or pedestals for el-az tracking. For full information, write:

A S I

ANTENNA SYSTEMS INC.
HINGHAM, MASSACHUSETTS

FOR ANSWERS TO PROBLEMS IN THE DESIGN, FABRICATION AND INSTALLATION OF ANTENNA SYSTEMS, ASK ASI!

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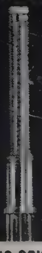
QUIET PLEASE!

Electrons faithfully obey this command in their movements between brush and ring in Electro-Tec slip-ring assemblies. Materials are so carefully selected, precious metals so accurately deposited and machined, and design so skillfully integrated, ETC slip-ring assemblies transfer electrons in hushed electrical silence.

Do you have an electrical noise problem in radar, fire-control, inertial platforms or any other type of moving equipment? Learn how the electrical silence of an ETC slip ring can add accuracy and reliability to your system.

Write today for the new ETC brochure on large slip-ring assemblies.



ELECTRO-TEC CORP.
South Hackensack, N. J.
Blacksburg, Va.—Ormond Beach, Fla.

WEST COAST LICENSEE: PACIFIC SCIENTIFIC CO., P.O. BOX 22019, LOS ANGELES 22, CALIF. PAT. NO. 2,696,570

Industry News

(*Continued from page 48*)

ADMIRAL FRESEMAN NAMED TO NEW POST

Appointment of Rear Admiral Willia L. Freseman, USN (Ret.), to a new po of Assistant to th President of Radi Engineering Labo atories, Inc., Lo Island, N. Y., communications subsidiary of Dynam Corporation of America, has been announced by Fra A. Gunther, RE president.

Mr. Freseman previously was vice president of International Standard Engineering, Inc., a subsidiary of International Telephone an Telegraph Corp. and also Manager of th IT&T Projects Group. In 1952, h founded the Radar Research Laborato of the University of Miami, which h headed as Director, and also served a professor of electrical engineering at th University.

His prior naval career of more than 2 years encompassed a number of majo naval communication assignments, as we as line commands through World War I A graduate of the United States Nava Academy (BS 1922), Mr. Freseman als holds a master of science degree fro Harvard University (1929) and a certificate from the Naval War College (1935

—*mwj*—

HECHTEL JOINS LITTON RESEARCH LAB

Dr. J. Richard Hechtel has joined th staff of the Research Laboratory of Litto Industries' Electron Tube Division, S Carlos, Cal., as a senior scientist. Th announcement was made jointly by D Norman H. Moore, vice president of Li ton and general manager of the tube division, and Dr. Joseph F. Hull, director the laboratory.

For the last three years Dr. Hecht has been head of the microwave tu branch, Naval Ordnance Test Statio China Lake, Cal. Previously, he was employed for seven years as research scienti and head of the microwave tube depar ment for Telefunken, GmbH, at Ulm Germany. Dr. Hechtel also was associated with C. Lorenz A. G., Oberessli gen/Stuttgart, Germany, for two years.

Since receiving his doctorate at th University of Technology, Munich, Germany in 1940, Dr. Hechtel has specialize in reflex klystrons, traveling-wave tube triodes and the interaction of electrons.

Dr. Hechtel is a senior member of th Institute of Radio Engineers and is associated with the Research Society America and the Professional Group f Electron Devices.

—*mwj*—

(*Continued on page 56*)

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THE ULTRASTABLE MICROWAVE OSCILLATOR

is a general-purpose signal source and as a secondary frequency standard.

by BYRON R. YOUNG
Engineer, Instrument Division
LABORATORY FOR ELECTRONICS, INC.

It is well known that an extremely stable microwave oscillator is required as the local oscillator in moving-target-indicating radar systems. In this application, the sub-clutter visibility and cancellation ratio aspects of the over-all system depend largely on reducing and maintaining the peak f-m deviation of the local oscillator to a few cycles per second.

It is not so well known that oscillators of exceptional stability are and should be used in many newer fields. As a result of steadily growing activity in the microwave field and the need to measure with greater accuracy and precision, the excellent characteristics of modern stable oscillators should be fully realized.

In most applications, three basic stability characteristics are required: (1) freedom from residual f-m (short-term stability), (2) freedom from drift (long-term stability), and (3) improved power stability. For LFE's 814-Series oscillators, the residual f-m is down to approximately five parts in 10^8 or better, drift is one part in 10^6, and power stability is ± 0.25 db.

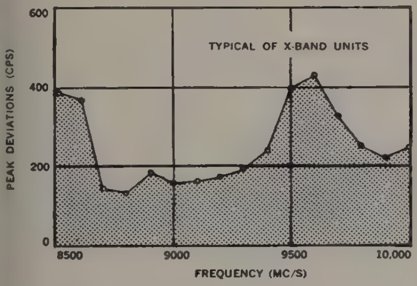


Figure 1

To illustrate the frequency stabilities directly, figure 1 shows residual f-m in cps plotted as a function of output frequency in mc/s at X-band. Most of the residual f-m is noise, a non-periodic function. As might be expected, the principal periodic contribution is from power-line frequencies as shown in figure 2.

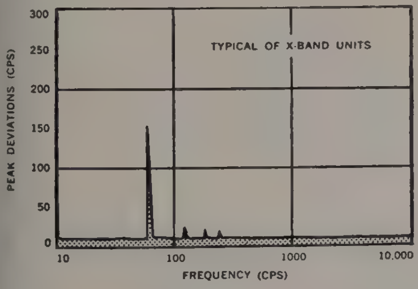
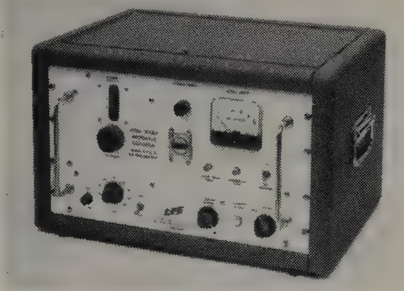


Figure 2

The purity of signal, the power stability, and the small drift enhance measurement accuracy. Wherever high resolution is needed to determine fine detail, the ultrastable oscillators are invaluable. Also, the extremely high signal-to-noise ratio permits measurements at very low levels. The use of these stable oscillators makes measurements possible that otherwise could not be made.



Model 814-X-21

The practical applications for 814 oscillators are becoming more numerous with time. To name a few, they are used as parametric amplifier pumps in radio astronomy; as r-f sources in microwave spectroscopy, in low-noise receiver development, in low-order VSWR measurements; and as local oscillators in high-performance MTI radars and other receiver-like devices. And in any application where the measurement sequence extends over a considerable length of time, the power stability and freedom from drift are particularly appreciated.

For general-purpose laboratory use, ease of use is as important as stability. In this respect, the 814 oscillators are really outstanding. One-dial control is closely approached. The direct-reading tuning dial, illustrated in figure 3, actually controls the dual-mode, invar reference cavity, a precision wavemeter accurate to 0.1 percent of reading. By means of a calibration chart, substantially greater absolute accuracy can be attained.

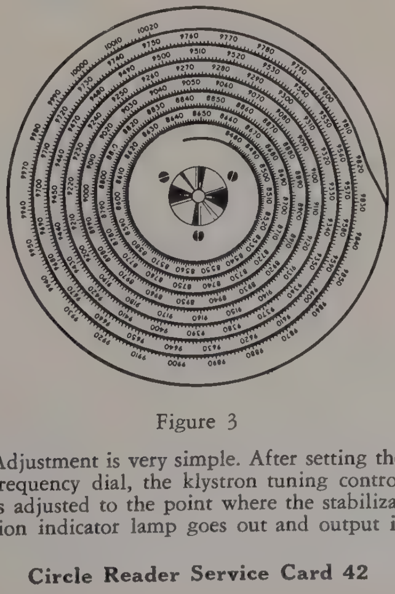


Figure 3

Adjustment is very simple. After setting the frequency dial, the klystron tuning control is adjusted to the point where the stabilization indicator lamp goes out and output is maximized. Should stabilization become lost for any reason, the lamp lights as a warning.

An 814-Series oscillator can be amplitude modulated up to 15% at 1000 cps by means of an internal oscillator-modulator, and at other frequencies by an external modulator. Higher modulation percentages can be obtained with an external gyrator. Also, the output can be frequency modulated up to 0.01 percent of frequency.

In addition to its many uses as a general-purpose signal source, an 814-oscillator is also used as a secondary frequency standard. By means of a transfer oscillator and counter, models of which are commercially available, any frequency can be set into an 814 to a high degree of accuracy. Then, the drift of an 814 is so small that it can be depended upon for long periods of time as a secondary standard. Also, these ultrastable oscillators make excellent exciters to drive multiplier chains for the generation of much higher frequencies or great accuracy.

SERIES 814
STANDARD MICROWAVE OSCILLATOR LINE

Oscillator	Frequency in mc/s	Nominal Power (milliwatts)
L-BAND		
814-L-9	2000-2500	100
S-BAND		
814-S-1	2500-3050	75
814-S-2	2950-3600	80
814-S-31	3700-4300	1000
C-BAND		
814-C-1	5100-5900	60
814-C-1A	5100-5900	60
814-C-10	5400-5900	200
814-C-31	5925-6425	1000
X-BAND		
814-X-1	8500-10,000	80
814-X-2	9000-10,500	55
814-X-3X	9800-11,200	250
814-X-21	8500-10,000	500
K-BAND		
814-K-21	12,800-14,500	100
814-K-22	14,500-17,500	100
817-K-24	23,000-25,000	40

In addition to the models listed, packaging and engineering modifications are available to meet particular requirements including those of systems in which an 814 is a component. For Bulletin 814, or for particular information, write to Mr. Perry Pollins at the address below.

If you are also interested in measuring frequency stability, ask for a bulletin on the Model 5024 Stability Tester.

LABORATORY FOR ELECTRONICS, INC.
Instrument Division
714 Beacon Street, Boston, Massachusetts

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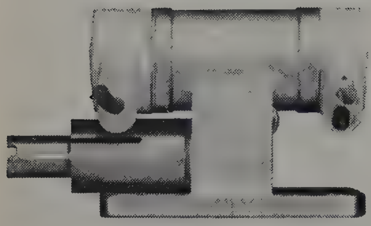
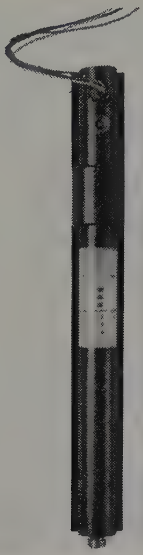
here today:


Eimac 1K20 Series
Reflex Klystrons
Tuning Range: 8.5 to 11.5 kMc
Typical Output: 75 mW


Eimac X778 TWT
Frequency: 5.0 to 11.0 kMc
Small Signal Gain: 60db
Minimum Power Output: 1 watt

Eimac X-747 Voltage-
Tunable Magnetron
Tuning Range: 400 to 1200 Mc
Nominal Power Output: 100 mW

here tomorrow:

New Eimac X- and K-band one watt reflex klystrons with excellent stability and low-noise characteristics.

New Eimac higher powered TWT's to meet the requirements of commercial and military applications.

New Eimac S-band Voltage-Tunable Magnetrons retaining desirable L-band linearity and long life.

And there's more to come! Behind the scenes a fully staffed Eimac Microwave Laboratory offers the broadest possible capabilities for new tube development. You'll find the most advanced answers to your microwave needs in Eimac . . . world leader in negative grid tubes, microwave tubes, amplifier klystrons. Write: Microwave Products, Eitel-McCullough, Inc., San Carlos, California.

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A partial view of Device Development Laboratory.

INTRODUCING

MICRO STATE Electronics Corporation

Murray Hill, New Jersey

Micro State — an acronym for microwave and solid state — chose its name in order to emphasize the basic philosophy of a closely integrated approach in the utilization of solid state techniques for microwave applications.

History

Need for a company, with the philosophy adopted by Micro State, was dictated primarily by the rapid shift in emphasis in the microwave field from conventional hardware toward solid state components. Research items such as ferrites, paramagnetic crystals, varactors, and tunnel diodes were being translated into new and useful components such as isolators, circulators, masers, parametric amplifiers, harmonic multipliers, oscillators and low noise amplifiers. The founders of Micro State felt a new approach would be required in the microwave solid state field if optimum designs were to be realized to meet the requirements of systems engineers.

The implementation of the Micro State approach required that the solid state people work hand in hand with the microwave people. By interchange and feedback of information, it would be possible for the microwave group to specify the detailed electrical characteristics required of the devices to be supplied by the solid state group, and for the solid state group to have first hand knowledge of the needs of the microwave circuit designer. In addition to realizing both optimum solid state circuits and devices, it was felt that the time interval between applied research and product availability could be minimized.

This concept brought the five founding members of Micro State together and led them to action. The background and experience of the founders covers all phases of microwave components, semiconductor devices, semiconductor materials, and solid state devices. Dr. S. Weisbaum, President of Micro State, was Manager of a Solid State Microwave Group, which he had organized, at the Communications Systems Laboratory of RCA. His experience was in the fields of parametric amplifiers, tunnel diode amplifiers and solid state devices for systems applications. In addition, he had worked at Bell Telephone Laboratories from 1953-1957, where he had specialized in the development of microwave ferrite components, including the field displacement isolator.

John Sie (Vice-President, in charge of the Microwave Component Division) was a member of the same group at RCA, where he had demonstrated an ability in the field of solid state microwave components. His activities cov-

The founders of Micro State planning product program are (left to right) Saul Lederhandler, director of Materials Developmen Aaron Kestenbaum, vice president of Materials and Devices; Samuel Weisbaum, president; John Sie, vice president of Componen and Lorne Armstrong, director of Device Development.

ered parametric amplifiers of both the cavity and traveling wave type, tunnel diode amplifiers and oscillators, active filters and other solid state components.

At RCA Somerville, Mr. A. L. Kestenbaum (Vice-President, in charge of the Semiconductor Devices and Materials Division) was Manager of Industrial Transistor Engineering. His experience in the semiconductor field, his contributions to the early development of new semiconductor devices such as the drift transistor, and his knowledge of production techniques made him a natural choice to head The Semiconductor Group. Dr. L. Armstrong, (Director of Device Development) who had recently received the David Sarnoff Gold Medal Award, has been in the forefront of most of the major semiconductor developments in the last ten years. He has published papers on germanium P-N junction devices and alloy junction type transistors; silicon diffused devices with mesa structures; high frequency switching transistors; high temperature diodes, transistors and varactors.

S. Lederhandler (Director of Materials Development), who was Manager of an Advanced Device Development group, was experienced in the field of semiconductor material development and specialized device and material measurements. He has performed fundamental studies on silicon and gallium arsenide, such as infrared absorption and Hall mobility measurements at low temperature.

Semiconductor Materials, Semiconductor Devices, and Solid State Microwave Components — this was the package presented to Apollo Industries, Inc. In short order, a group of technical people, with a new approach, found itself solidly financed.

Since its incorporation in Delaware on July 29, 1960, Micro State has grown rapidly. Its staff now consists of 35 people, more than half of whom are top technical personnel. William Crowe, Manager of Microwave Component Development, with more than ten years experience in the microwave field, is directing work on tunnel diode amplifiers and oscillators. P. Widenor is Production Manager in this area. Mr. J. Kouzoujian and Mr. E. Hickey are members of this group. In the semiconductor area, Mr. R. Durnwirth, Mr. A. Wheeler, Mr. M. Kennison and Mr. V. Giorgio are Members of the Technica Staff. In the Sales Department, Mr. R. Kolts, formerl Marketing Manager of Airtron, is in charge of Micro wave Components, and Mr. A. Graydon, formerly Sale Manager at Hughes, is in charge of Semiconductor Pro ducts.

Company Activities

The primary strength of Micro State resides in th technical competence of its personnel. This factor, to gether with its integrated design concept, enables th company to offer optimized products in the areas of soli state microwave components, and semiconductor device and materials. In addition, Micro State has the capabilit and the willingness to perform advanced R&D work i the above fields, where creativity and technical know-ho are the basic ingredients for successful performance.

Micro State's product line now includes such divers items as low noise tunnel diode amplifiers, tunnel diod oscillators, parametric amplifiers, solid state microwav switches, germanium tunnel diodes, gallium arsenid varactors, gallium arsenide rectifiers, and gallium arsen ide single crystals. Many of these items can be obtaine on an "off-the-shelf" basis.

Because of its product line, extending from basic sem conductor materials, through semiconductor and soli state devices, to the final microwave solid state compon ents, Micro State had to construct a special building con sistent with these activities. Located at 152 Floral Avenue Murray Hill, New Jersey, this structure contains 12,60 square feet, and permits R&D work and production i both the Semiconductor and Microwave fields. The build ing has been designed to allow for future expansion t 40,000 square feet on the same property. This additiona space can become available on short notice.

The semiconductor laboratory is capable of growin single crystal material, preparing the crystal for devic fabrication and performing such diverse fabrication op erations as alloying, diffusion, vacuum evaporation o metals, contacting to small areas and mounting the activ device in enclosures. In addition, test equipment is available to measure both static and dynamic electrical characteristics of conventional and microwave devices.

The semiconductor manufacturing area can presently support the manufacture of semiconductor materials and a large number of semiconductor devices.

The Components Division has an engineering laboratory capable of performing all phases of evaluation and precision measurement in the communications field covering from audio frequencies to the millimeter wave region. It has facilities to perform basic ordinary measurements such as VSWR, insertion loss, power, gain, bandwidth, alignment, frequency, etc., as well as specialized precision measurements for very low noise systems, receiver sensitivity, wave analysis, frequency stability, phase sensitivity, harmonic distortion, extreme high and low temperature environmental tests, dynamic characteristics of active solid state devices, FM measurements, antenna pattern, etc.

A large portion of the new plant is devoted to the assembly and manufacture of microwave and UHF components. Production facilities are flexible so as to handle custom designed units on a prototype basis, or large scale manufacturing for system requirements. The precision machine shop is fully equipped with machinery to fabricate prototype models and provide general service for both the Device and Components Divisions.

Corporate Information

At the present time, Micro State is privately held. Apollo Industries has a majority interest in the common stock, and holds all of the preferred. The remaining common stock is distributed among the Scientists of Micro State. Additional common stock has been authorized for stock options to attract key personnel.

The composition of the Board of Directors is as follows: Dr. S. Weisbaum, Dr. L. Armstrong and Mr. B. Levin from Micro State; Mr. O. Sowerwine from Hayden-Stone; Mr. A. Arthurs from Arthurs-LeStrange; and Mr. I. Levitt, Mr. D. Lowenthal, Mr. M. Chatkin, and Mr. I. Novick from Apollo Industries, Inc.

In addition to the corporate officers previously mentioned, Mr. B. Levin is Vice-President and General Manager, and Dr. J. Singer is Vice-President-Finance. Mr. B. Levin has had a number of years of experience in this executive capacity in industry both in the U.S.A. and the Union of South Africa.

Dr. J. Singer as Treasurer and Vice-President-Finance has had 20 years experience in finance and administration. He holds a PhD in Economics.

The financial support which has been provided by Apollo is adequate to meet the needs of Micro State for several years. Additional financial support will be provided, if required, for large production contracts.

In a small electronics company, the key factors which are required for a successful operation are top technical personnel with a large amount of drive, ideas which can be rapidly translated into product availability, an intimate knowledge of the needs of the customer, and sound financial backing. Micro State has assembled these items. The test of its ability to translate them into a profitable business venture will be determined by how well Micro State meets its projected sales goal of 1.5 million from May 1961 to May 1962.

LOW NOISE

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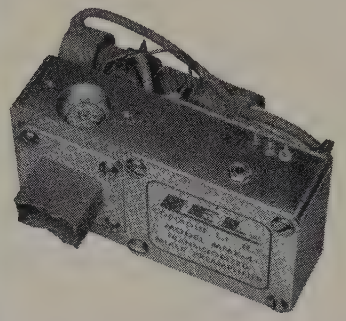
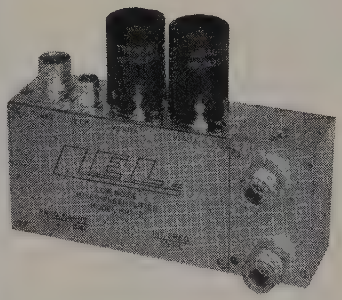
The CBH, CCH, CDH, and CEH Series of Integrated Waveguide Mixer-Preamplifiers.
Noise Figure: 7.5db



for
X Band
The XAH, XBH, XCH, and XDH Series of Integrated Microwave Mixer-Preamplifiers.
Noise Figure: 7.5db



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The LAC, SAC, SBC, and CAC Series of Coaxial Mixer-Preamplifiers.
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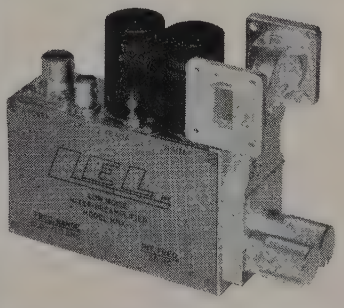

for
KA and KU Bands
The KAH, KBH, KCH, and KDH Series of Integrated Microwave Mixer-Preamplifiers.
Noise Figure: 10.0db

LEL stocks the most complete line of low noise microwave Mixer-Preamplifiers available ANYWHERE.

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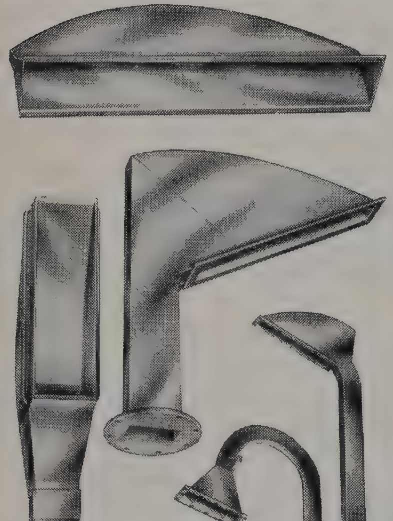
The closer tolerances and better joint design inherent in Belz Aluminum Dip Brazing results in better electrical characteristics. Superior quality, as well as customer savings are assured through simple fixtures, minimum tacking and self-locating parts.

Why not discuss your next dip-brazing problem with Belz?



Request descriptive brochure ADB. For quotation on specific aluminum dip brazing production problems — write, wire or call. Inquiries concerning development and/or manufacturing of microwave assemblies and system components are also welcome.

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Pioneer 2-1010

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Industry News

(*Continued from page 50*)

CANADA NAMED RAYTHEON ENGINEERING MANAGER

Alfred H. Canada has been named manager of engineering for Raytheon Company's Santa Barbara, Cal., operations, it has been announced. He succeeds Stanley D. Crane, who has left the company.

Canada was most recently a technical consultant on infrared and optical techniques for the Advanced Research Projects Agency. Prior to that, he had been with General Electric Co. for 20 years in engineering and managerial posts associated with that company's infrared and optical programs.

A 1940 graduate of Oregon State College, he holds a Bachelor of Science degree in electrical engineering. He has a number of patents on infrared devices, and has published many articles in this field.

He is a member of the American Institute of Electrical Engineers, chairman of the Institute's subcommittee on infrared applications, and a member of its committee on electronics.

—*mwj*—

PANTELL BECOMES CONSULTING SCIENTIST AT LEWIS AND KAUFMAN

Dr. Richard Pantell, associate professo of electrical engineering, Stanford University, has become affiliated with Lewi and Kaufman Electronics Corp., Lo Gatos, Cal., in the capacity of consultin scientist.

Dr. Pantell, while retaining his post a Stanford, will serve as Consulting Scientist to both the Tube Division and Cascade Research Division of Lewis and Kaufman

With the Tube Division Dr. Pantel will concentrate primarily upon developmental work on klystrons, backward wave oscillators, and traveling-wave tubes. At Cascade Research Division he will work with H. Chait, chief scientist, who wa formerly with the Naval Research Laboratory. At Cascade, emphasis will be placed upon advancements in microwave ferrit and ferroelectric phonomenon (application).

Since 1957 Dr. Pantell has been working at the W. W. Hanson Microwave Laboratory, Stanford University, on millimeter wave generation, microwave applications for ferroelectrics, and low noise amplifiers.

—*mwj*—

(*Continued on page 58*)

NOW THE FLATTEST COAXIAL ATTENUATORS AVAILABLE

RLC ELECTRONICS INC.

RLC A25
COAXIAL ATTENUATOR

PART NO.	Atten. Value (db)	Variation* (db)	Max. VSWR	Frequency (kmc)
A25-3	3	±0.3	1.3	0.5-11
A25-6	6	±0.4	1.3	1-11
A25-10	10	±0.5	1.35	1-11
A25-20	20	±0.7	1.35	2.11

*Variation of atten. as a function of Frequency.

The most recent advances in resistor film technology insure stability, power handling capabilities and mechanical ruggedness.

Type N Connectors—$32.50 each from stock.
Other Connectors and attenuation values available upon request.

RLC

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℞ how to cure traveling wave tube headaches

If you have TWT headaches—finding a microwave amplifier *now*—which produces high gain and wide bandwidth *with* high average and peak powers—Hughes may have just the prescription for you. Hughes TWT's provide all these desirable features with built-in long life, ruggedness and dependability. They fully exploit the advantages of permanent magnet periodic focusing in both glass and metal-ceramic structures, and many are available in either gridded or ungridded versions.

CREATING A NEW WORLD WITH ELECTRONICS

HUGHES

HUGHES AIRCRAFT COMPANY
MICROWAVE TUBE DIVISION

typical twt's available now:

311H 2.0-4.0 KMC Gridded 1 KW minimum peak power output, 1% duty, 36db small signal gain @ 50 mw input. Weight 13 lbs. Length 17-7/16″.

312H 2.0-4.0 KMC Gridded 1 KW minimum peak power output, 1/2% duty, 36db small signal gain @ 50 mw input. Weight: 11 lbs. Length: 15-3/8″.

304H 2.0-4.0 KMC Ungridded, 1 KW minimum peak power output, 1% duty, 37db small signal gain @ 1 mw input. Weight: 12-1/2 lbs. Length: 17-31/32″.

307H 8.5-9.5 KMC 50 KW minimum peak power output (500 watt average), metal-ceramic construction, 54db saturation gain, 1% maximum duty cycle, beam voltage = 38 kv. Wt. 21 lbs. Length: 24″.

Hughes also has a complete line of K_u-band backward-wave oscillators for commercial and military applications.
Write or telephone today for full information or a catalogue concerning the broad line of Hughes TWT's available in L, S, C & X bands.
Hughes Microwave Tube Division, P. O. Box 90427, Los Angeles 45, California.

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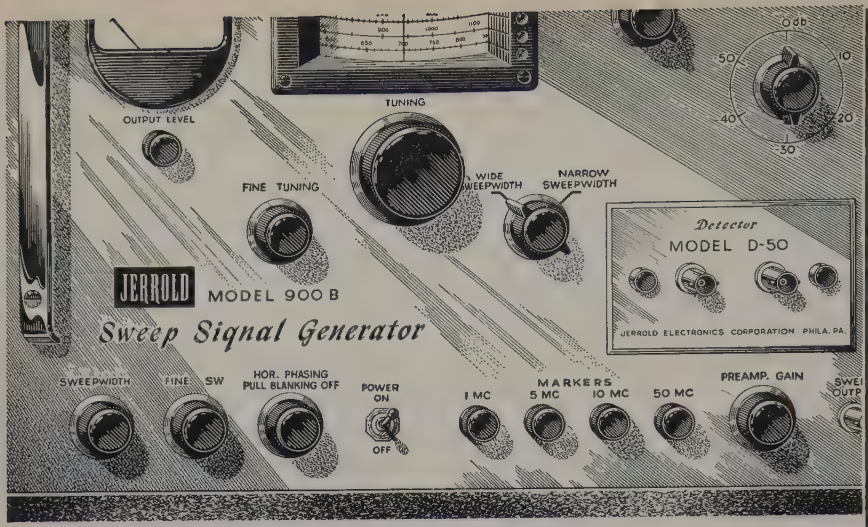

New Jerrold WIDE PLUS NARROW SWEEP SIGNAL GENERATOR Model 900 B

UNUSUAL STABILITY IN SWEEP WIDTHS FROM 10 KC to 400 MC

Here, in one instrument, you can handle practically any sweep signal requirement from 500 kc to 1200 mc—VIDEO, IF, VHF, and UHF. In addition to both wide and narrow sweep capabilities, the 900 B features an accurately calibrated frequency dial; built-in crystal controlled harmonic markers (at 1, 5, 10 and 50 mc intervals); individually controlled marker output; built-in dc coupled oscilloscope preamplifier; high level metered output and built-in attenuator. **Price $18800* f.o.b. Philadelphia**

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**Prices and specifications subject to change without notice.*

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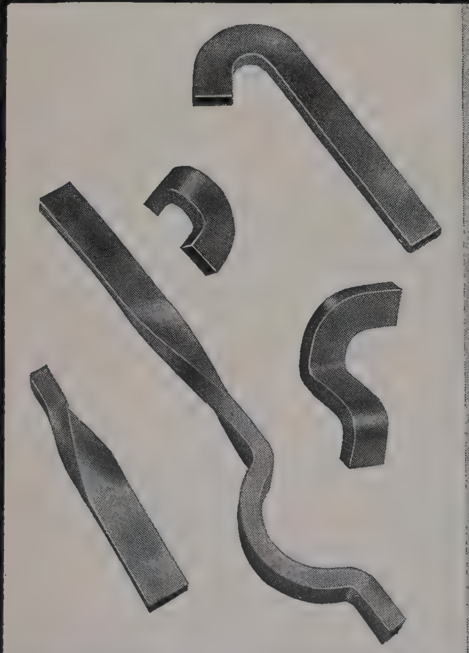

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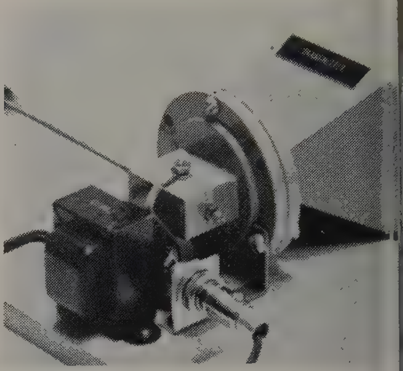
Industry News

(*Continued from page 56*)

TINY TRANSMITTER DEMONSTRATED BY GE



A miniature transmitter which uses single tiny ceramic receiving tube osci lating at 7300 megacycles has been demon strated by the General Electric Receivin Tube Department, Owensboro, Ky.

The transmitter, and its power suppl are so small they can be held togethe in the palm of the hand. Power outpu of the transmitter is about 30 milliwat and its range is approximately 50 fee Range could be substantially greater, de pending on the sensitivity of the receive

The significance of the demonstratio is that it shows radio signals at this fr quency (7300 Mc) can be emitted with relatively inexpensive tube-cavity comb nation, according to James W. Rush, ap plication consultant.

The tube used is a re-entrant cavit version of the 7486, one of a line of 1 registered types of small ceramic receivin tubes which are beginning to be used mor widely in military and space communica tions.

—*mwj*—

MET JOINS KANE ENGINEERING LABORATORIES

Dr. Victor Met has joined Kane Eng neering Laboratories, Palo Alto, Cal., a manager of the Waveguide Componen Research and Development Group, ac cording to Kirkwood G. Colvin, genera manager.

Dr. Met has been with General Electri Microwave Laboratory, Palo Alto, sinc he came to this country as a permanen resident from Austria in 1955. At GE h developed the first practical circuits cap able of binary switching in the nanosecon range and contributed a major portion o the successful development of high powe absorptive microwave harmonic filters.

His most recent assignment at GE gav him responsibility for research and devel opment for depressed collectors on hig power klystrons. From this work evolve the design of a dual state collector re dering an efficiency increase by ten pe centage points and an X-ray reduction b one order of magnitude on a one M peak X-band klystron.

—*mwj*—

(*Continued on page 60*)

RF PRODUCTS BUILDS ANVIL RUGGEDNESS INTO PRECISION COAXIAL SWITCHES-RELAYS...

pring-leaf switching blades, gold-plated silver contacts and impedance matched connectors keep sertion loss and VSWR (1.3 @ 4,000 MCs) low, Crosstalk high (in decibels down). Electro-mechanically ctuated models operate and release in 8 to 20 milliseconds, depending on type and function, with a roven mechanical life of 1,000,000 cycles minimum when operated under 10 cps. / Available for fast elivery from factory stock in a large variety of configurations and functions, including SPDT, DPDT, P4T, 1P6T, 1P12T and Transfer types.

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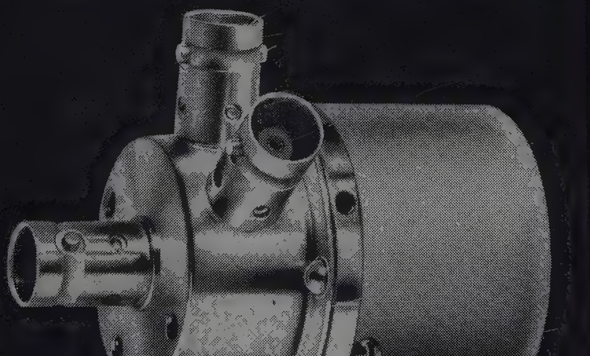

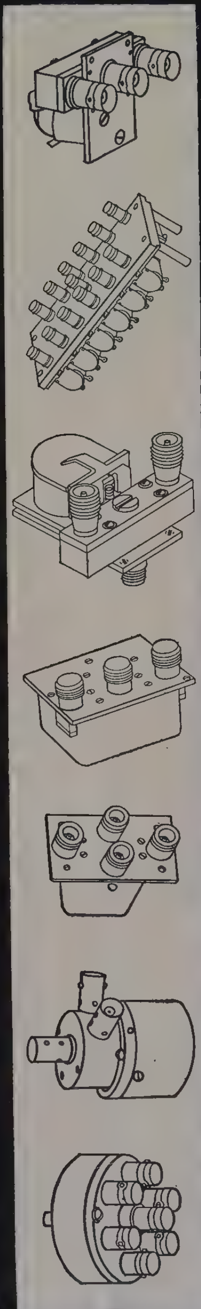

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KLYSTRONS

Important new additions to the long established range of 2KV Klystrons now extend the overall frequency coverage to 12.0—40kMc/s.

Type No.	Freq. kMc/s.	Typical Power Output † mW	Output
R9521	35 — 40	50	RG96/U with British flange
R5146	34 — 36·5	60	,,
R9546	32 — 37·5	50	,,
R9518	27·8 — 32·2	50	,,
R9547	24 — 27·8	50	,,
R9602	22 — 26	85	RG53/U with UG595/U
R9621	20 — 24	100	,,
R9622	18 — 22·5	100	,,
R9626*	15 — 18	100	RG91/U with UG419/U
R9625*	13·5 — 16·5	100	,,
R9624*	12 — 15	100	,,

*Provisional data. † Matched load VSWR <1·1

TYPICAL OPERATION:—

Vres	2kV		Ires	12mA
Vh	6·3v		Ih	0·8A
Vref	—100	to	—600	30μA max.
Vgrid	0	to	—200	100μA max.
ETR	40—60 Mc/s.			

The extensive range of EMI Special Tubes includes:—Plug in Klystrons and External Resonators, Photomultipliers, Camera and C.R. tubes.

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Industry News

(*Continued from page 58*)

NBS APPOINTS UTLAUT CHIEF

William F. Utlaut, a specialist in the use of radar techniques to study the ionosphere and upper atmosphere, has been appointed chief of the National Bureau of Standards' Section on High Frequency and Very High Frequency Research according to an announcement by Dr. F. W. Brown, Director of the NBS Boulder Laboratories, Boulder, Col. This section is a part of the Radio Systems Division within the NBS Central Radio Propagation Laboratory.

Since joining NBS in 1952 Utlaut's studies have been concerned with increasing the understanding of the ionosphere and its effect upon radio waves. His efforts have ranged from the design of special electronic equipment for radio research to theoretical studies of ionospheric propagation.

The wide scope of these studies is indicated by the programs currently being conducted under Utlaut's direction. These include research on radio systems for long distance communication circuits and for the detection of missiles and nuclear detonations, research on the scattering of VHF signals by one of the lower layers (D region) of the ionosphere, and a study of whether or not lines of force in the earth's magnetic field could be used to bounce signals between the northern and southern hemispheres of the globe.

—*mwj*—

PRD PROMOTES FISHER

Louis H. Fisher has been promoted t the position of chief applications enginee at PRD Electronic Inc., Brookly N. Y., it was di closed by Harry C Nelson, director marketing.

Mr. Fisher, member of PRD Applications En neering staff for th past five years, wi direct the expan ing applications e gineering activities to its group of micr wave specialists.

During recent years, Mr. Fisher h conducted numerous microwave measur ment symposia for the purpose of intr ducing this art to electronic enginee trained in lower frequency techniques. I addition to the microwave and test instru ment experience gained at PRD, he ha been engaged in the design of transmi ters, receivers, and radio proximity fuze During World War II he was an electron ic specialist in the U. S. Navy, gainin experience in radar, sonar, loran, fire co trol, and countermeasures systems.

—*mwj*—

(*Continued on page 62*)

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Transitions, Fabrications and
complete assemblies to your prints.

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UP to 150 KMC at −45 VOLTS BV!

WITH NEW SYLVANIA SDV-4166 EPITAXIAL SILICON VARACTOR DIODE

Through the use of epitaxial techniques, SYLVANIA has proven the practicability of manufacturing Silicon Varactors with cutoff frequencies as high as 150 KMC at a 45-volt breakdown voltage. As an indication of the significance of this Sylvania development, previously available diodes made with conventional techniques and with equivalent breakdown voltage exhibit cutoff at less than 15 KMC at −6 volts.

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Industry News

(*Continued from page 60*)

DIELECTRIC'S BROWN NAMED IRONRITE PRESIDENT

Dr. Charles D. Brown, President Dielectric Products Engineering Compan Inc., has bee named President the board of dir tors of Ironrite In Mt. Clemens, Mic Other offic elected were C. Mollhagen, vic president; W. Turner, vice pre dent and treasure John H. Uhlig, se retary; James I Tracy, assistant secretary. At the san time Don Petty was elected chairman the board, replacing H. A. Sperlich wh was named chairman emeritus.

Dr. Brown replaces Mr. Mollhage who becomes vice president of Ironri and president of the Ironer Division. D Brown will continue his present positio as President of Dielectric Products Eng neering Company, Inc., a wholly own subsidiary of Ironrite, Inc.

A graduate of the University of Mai and Harvard University, Dr. Brown joine Dielectric in 1945 as Chief Research an Development Engineer. He was elect Vice President in 1947 and President 1953.

The stockholders of Ironrite also r elected ten directors, leaving the boar unchanged from the previous fiscal yea Directors re-elected are Dr. Brown, C Edward Horne, Robert J. Kennedy, Josep Kinney, Jr., Howard A. Lewis, C. E. Mol hagen, Don Petty, Robert S. Potter, H. A Sperlich and John H. Uhlig.

—*mwj*—

FIDELITONE ACQUIRES MICROWAVE FIRM

Douglas F. Hudson, president Fidelitone, Inc., Chicago, Ill., manufa turer of replacement phonograph needle has announced the acquisition of the JV Microwave Co., Brookfield, Ill., manufa turers of a complete line of triode cavitie

"As the electronics field pushes rapid into the forefront in all phases of i dustrial activity, not even the most su cessful company can afford to relax or b complacent," Hudson said. "For the pa two years we have been alert for ne products which would fit our manufactu ing techniques. After screening severa hundred manufacturing companies, JV was chosen because the microwave indu try shows unusual growth potential.

"While this is a comparatively ne field," Hudson concluded, "Fidelito has acquired a vigorous young firm th brings with it imagination and administra tive and technical skills."

—*mwj*—

MCS MOVES TO LARGER PLANT

Microwave Components & Systems Corp. has moved from its Temple City plant to a larger, modern, air-conditioned manufacturing facility in Monrovia, Cal. The move will allow continued expansion for the custom microwave and waveguide components division and for both mechanical and microwave quality control departments.

According to Louis Della Penna, MCS president, the move was needed to handle the expansion of operations due to increased sales.

— *mwj* —

THEME SET FOR COMPUTER CONFERENCE

The 1961 Eastern Joint Computer Conference has announced that the theme for this year's conference, to be held December 12-14 at the Sheraton-Park Hotel in Washington, D.C., will be: "Computers — Key to Total Systems Control"

Bruce G. Oldfield, Program Chairman, stated that this theme reflected one of the most significant trends in modern computer technology. "Until quite recently, computers were considered to be data processing ends in themselves," Mr. Oldfield pointed out. "Now they are more and more being treated as merely one element — although the most vital one — in total systems for government, defense, industry and business management operations. Other important elements in the closed loop of the 'total system' are data acquisition, digital data communications, display, and actual control or guidance."

The 1961 EJCC will follow this total systems approach by presenting the latest advances in equipment and concepts leading toward computer control of present and future systems. Mr. Oldfield called for papers in such representative areas as: Business Management Control, Military and Space Command Control Systems, Industrial Process Control, Real Time Systems, Network Control, Man-Machine Systems, Self Organizing Systems, High Speed Digital Data Communications.

Each person wishing to contribute a paper to the program should submit two copies of both a 100-word abstract and a two-page summary to:

Bruce G. Oldfield
IBM Federal Systems Division
326 E. Montgomery Avenue
Rockville, Maryland

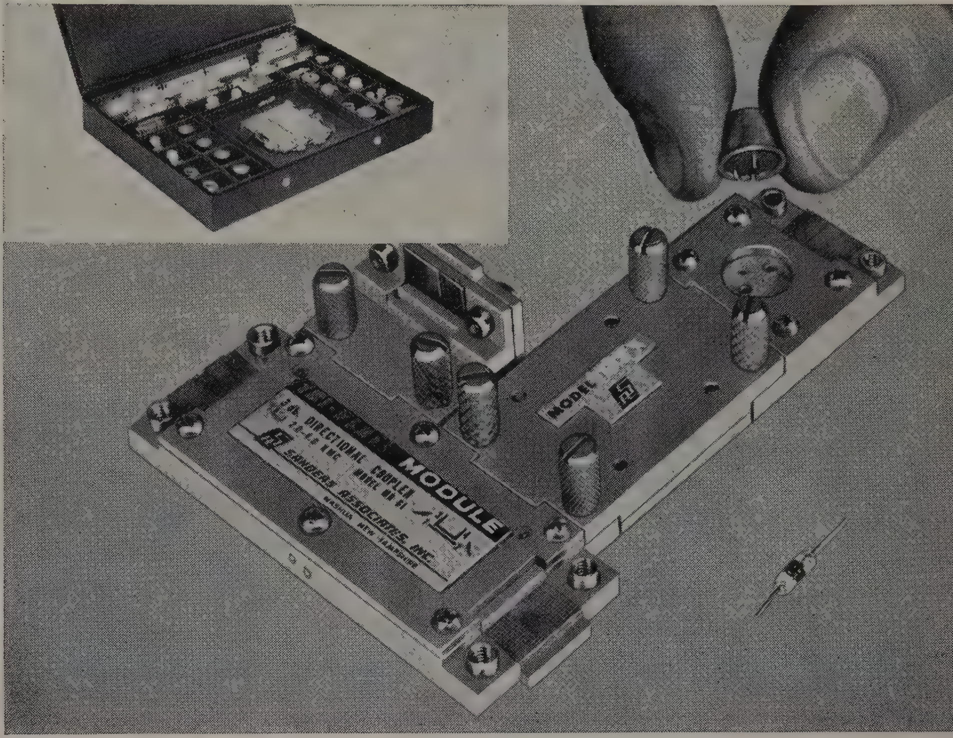
The deadline for submission of abstracts and summaries is June 20, 1961. Authors whose papers are chosen for presentation will be promptly notified.

Inasmuch as papers will be published prior to the Conference and made available to the attendees, the full text of papers chosen for presentation must be submitted to the Program Chairman by September 1, 1961.

— *mwj* —

(*Continued on page 73*)

NEW KITS SPEED BREADBOARDIN
OF ADVANCED VARACTOR, TUNN
DIODE AND TRANSISTOR CIRCUIT



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Abstracts from *Russian Technical Literature...* of interest to microwave engineers

Translations of complete papers can be made available by contacting Morris D. Friedman, Inc., c/o "the microwave journal," 1330 Beacon Street, Brookline, Massachusetts. Prices are dependent upon length of paper.

RADIOTEKHNIKA I ELEKTRONIKA, 5(1) (1960)

Sui Yan-Shen:

ELECTROMAGNETIC WAVE DIFFRACTION BY A GYROTROPIC SPHERE WITHIN A RECTANGULAR WAVEGUIDE.

pp. 15-26

The problem is analyzed of electromagnetic wave diffraction by a gyrotropic sphere within a rectangular waveguide in which a fundamental H_{10} type mode is propagated. Expressions are obtained for the expansion of normal H_{10} type modes into spherical waves for two cases, when the permanent magnetic field direction is parallel to the broad or the narrow wall of the waveguide. The amplitudes of the waves reflected from the sphere are calculated and the problem is solved of exciting a waveguide by reflected waves. *(6F, 4R)*

—*mwj*—

A. L. Mikaelian, A. K. Stoliarov, A. A. Vasil'ev:

INVESTIGATION OF THE SPECTRUM OF NATURAL OSCILLATIONS OF A CAVITY WITH A MAGNETIZED FERRITE.

pp. 27-38

An exact solution is obtained of the problem of the eigen frequencies of a cylindrical cavity (with $TM_{q,n,o}$ type oscillations) which contains a longitudinally magnetized ferrite cylinder of arbitrary radius. The eigen frequencies of the oscillations are determined and the field configuration is investigated.

An analogous problem is solved for the case of no cavity side walls. It is shown that for cylinders of infinitely small radius, the results are in agreement with the corresponding results of Walker [1], determined in the quasistatic approximation. *(15F, 5R)*

—*mwj*—

Ia. A. Monosov, A. V. Vashkovskii:

EXPERIMENTAL INVESTIGATION OF NONLINEAR PHENOMENA AT MICROWAVES.

pp. 105-116

Results are explained of an experimental study of the additional absorption in ferrites at high power levels in the 3 cm band, which are compared to theory. It is established that the additional absorption in the pre-resonance, magnetizing fields region consists of separate absorption peaks and an interpretation of this phenomenon is given.

The dependences of the threshold microwave field levels are presented, at which nonlinear phenomena occur, as a function of the saturation magnetization, the shape and size of the ferrite sample. *(8F, 4T, 9R)*

—*mwj*—

Ia. A. Monosov:

ON THE THEORY OF NONLINEAR PHENOMENA IN FERRITES AT MICROWAVES.

PT. I. PARAMETRICALLY COUPLED MAGNETOSTATIC OSCILLATIONS IN A FERRITE UNDER THE EFFECT OF PUMPING.

pp. 59-74

Long-wavelength electromagnetic oscillations of a small ferrite sample at the frequencies ω_1 and ω_2 are analyzed when powerful pumping at the frequency $\omega_3 = \omega_1 + \omega_2$ is present. It is shown that a parametric coupling arises between definite pairs of types of magnetostatic oscillations [9]. A characteristic equation is derived to determine the dependence between the resonant frequency and the magnetizing field of the parametrically coupled oscillations. If the resonance fields of the types of coupled oscillations coincide in the absence of pumping, then they are displaced by an order of magnitude of the half-width of the absorption line when pumping is present. *(3F, 12R)*

—*mwj*—

V. I. Zubkov, Ia. A. Monosov:

CERTAIN QUESTIONS OF THE THEORY OF PARAMETRIC AMPLIFIERS.

pp. 75-89

The eigen frequencies (parametric coupling frequencies) and the resonance curves of the parametrically coupled loops are investigated.

Curves of the change in the eigen frequencies (parametric coupling frequency) are calculated when the frequency of one of the coupled loops is returned and the returning region is determined, in which parametric excitation of the oscillations occurs.

The question is examined of the resistance induced in the loop by pumping. Conditions are determined under which the resistance has the maximum value. *(6F, 7R)*

—*mwj*—

A. I. Mikaelian, V. Ia. Anton'iants:

MICROWAVE FREQUENCY SHIFTING USING FERRITES.

pp. 90-104

The effect is analyzed of electromagnetic oscillations of two nearby frequencies on magnetized ferrite samples of small size. The amplitude is calculated of the voltage of the difference frequency, 30 Mc in the loaded loop, and results are presented on the measurements of this quantity for spheres of single crystal and polycrystalline ferrites of 0.5 - c mm diameter.

The measured and calculated values of the difference-frequency voltage for the single-crystal samples are in good enough agreement.

Large discrepancies between calculation and experiment are obtained for the polycrystalline samples. An attempt is made to explain these discrepancies.

Moreover, results are presented of investigations on cylindrical ferrite samples of different brands. The least transformation losses obtained in the experiment were —58 db for a 50 mV heterodyne power. *(9F, 3T, 10R)*

—*mwj*—

M. M. Koblova, L. V. Moskvina:

INVESTIGATION OF NONRECIPROCAL PHASE SHIFTS IN A COAXIAL LINE WITH A FERRITE

pp. 162-166

Certain computational results of an investigation of a plane-parallel analog of a coaxial line containing a ferrite-dielectric slab are explained. It is shown that an optimum configuration of the ferrite-dielectric slab exists to produce the maximum nonreciprocal phase-shift. Certain experimental results are presented.

(9F, 5R)

—*mwj*—

(*Continued on page 66*)

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6- 10.88 — 18.0 KMC	— 85 to —100 dbm
7- 18.0 — 26.4 KMC	— 70 to — 90 dbm
8- 26.4 — 44.0 KMC	— 60 to — 85 dbm

*measured when signal and noise equal 2x noise

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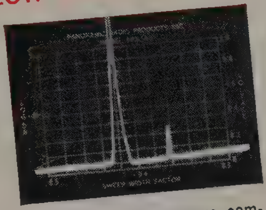
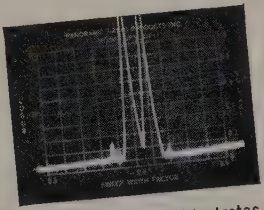


Extended dynamic range comparison of 2 signals on SPA-4a. Larger is + 15 db over full scale log. Smaller is at —28 db on scale or —43 db from larger. Note exceptional freedom from spurious. (Photo not retouched)



Distortion analysis illustrates SPA-4a wide range linearity. Odd-order distortion here is measured more than 50 db below level of 2 main tones (deflected 20 db above full scale). Photo unretouched.

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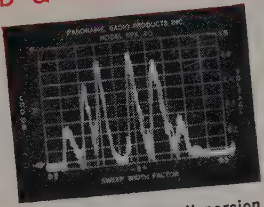
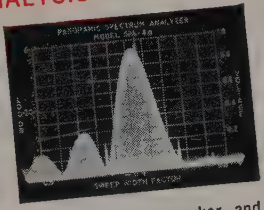


Narrow band 20 kc dispersion analysis shows unique resolution capability. Here, a 1000 mc FM signal with **2 kc** modulation is seen near first carrier null. Photo unretouched.



Pips of internal marker and sidebands (ext. mod.≈100 kc) accurately measure pulse width in spectrum of 10µs. radar pulse. Upper lobes seen to be very small. (Unretouched)

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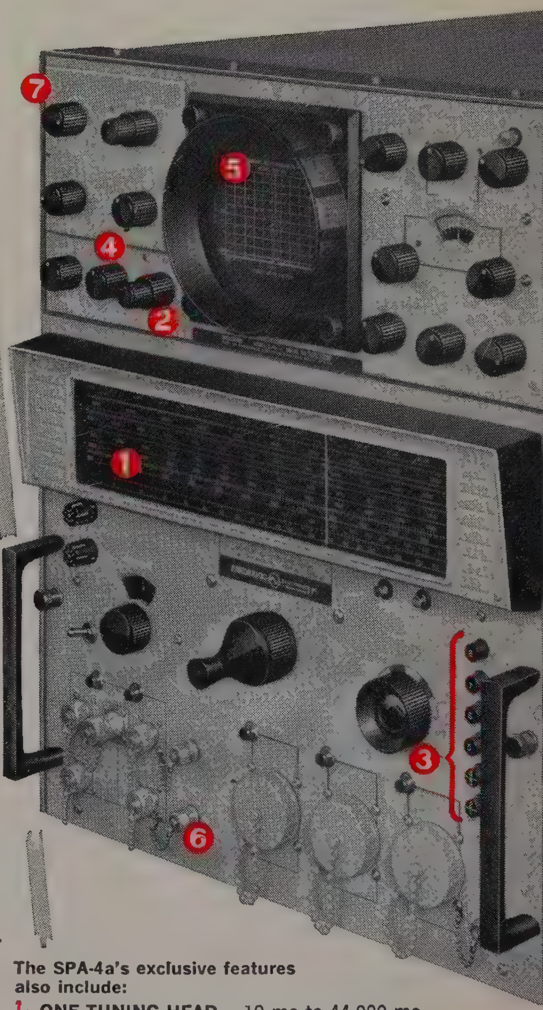

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Russian Abstracts

(*Continued from page 64*)

A. L. Mikaelian, N. Z. Shvarts:

CERTAIN QUESTIONS OF AN INVESTIGATION OF FERRITE AMPLIFIERS OF ELECTROMAGNETIC TYPE.

pp. 126-140

Questions of the theory and experimental investigation of ferrite amplifiers of electromagnetic type are examined.

Formulas are derived for a computation of the threshold pumping power taking into account the singularities of the amplifier cavities. The correspondence of these formulas to the results of an experimental investigation for different variations of degenerate amplifiers of electromagnetic type is established. This permitted optimum conditions to be found for reduction of the pumping power. The latter equals 500 W.

Results are also presented of an investigation of an electromagnetic amplifier of nondegenerate type. *(7F, 1T, 5R)*

—mwj—

Ia. A. Monosov:

ON THE THEORY OF NONLINEAR PHENOMENA IN FERRITES AT MICROWAVES.

Pt. II

PARAMETRIC PHENOMENA IN A FERRITE

pp. 278-287

The parametrically coupled magnetostatic oscillations of a ferrite sample, described in the first part (see [1]), are used to explain nonlinear phenomena in a ferrite at a high power level. It is shown that the equations for the oscillation amplitude in a ferrite agree with the equations for the currents in the loops coupled by means of the varying parameters. Formulas are obtained for the amplitudes of the coupled oscillations, the conditions of total cancellation of the damping of the coupled oscillations, the cancellation frequency bands, the width of the region of addition absorption at the pumping frequency.

An approximate computation using the formulas cited shows that the magnitude of the pumping power required for total cancellation of the damping of the oscillations in ferrites of garnet structure ($2\triangle H \underset{\sim}{} 1$ Oe) is on the order of 1 W. *(3F, 3T, 10R)*

—mwj—

V. P. Tychinskii, Iu. T. Derkach, V. V. Karpetskii:

EXPERIMENTAL INVESTIGATION OF A FERRITE AMPLIFIER.

pp. 288-295

The operation is investigated of a ferrite microwave amplifier in the electromagnetic region. The experimental circuit, method of amplifier precession angle. This permits a reduction in the requirements imposed on the ferrite element of the apparatus.

The measured value of the gain was about 22 db for excitation working powers on the order of 5 KW.

A convenient circuit for the investigation of the phase characteristics of the amplifier is proposed and realized. The results obtained agree with data published by other authors and confirm the parametric principle of the operation of the ferrite amplifier. *(12F, 12R)*

—mwj—

RADIOTEKHNIKA I ELEKTRONIKA, 5(4) (1960)

N. A. Khizhniak:

ENERGY LOSSES BY A CHARGED DISC MOVING UNIFORMLY IN A WAVEGUIDE.

pp. 654-661

Energy losses due to polarization of the medium and the Cherenkov emission by a charged disc moving uniformly in a slow wave waveguide. It is shown that the field generated by the disc consists of a field "entrained" by the disc and a field "separated" and the power fluxes and the energy expended by these fields are calculated. Coherence conditions are discussed for the motion of an extended disc in a waveguide in the case of sharp and diffuse boundaries. Coherence conditions are discussed for the motion of a chain of discs or bunches.

(6R)

—mwj—

RADIOTEKHNIKA I ELEKTRONIKA, 5(5) (1960)

L. G. Lomidze:

DESIGN OF A CHERENKOV RADIATOR IN THE MICROWAVE RANGE.

pp. 707-719

A computation is made of a waveguide Cherenkov radiator for relativistic bunched electron beams in the microwave range. It is shown that the waveguide construction of the radiator guarantees considerably larger radiation power than follows from computations for an unbounded dielectric medium with a channel for beam transmission. The dependence of the radiation resistance on the wavelength, lateral dimensions of the cylindrical waveguide and channel in the dielectric and also on the dielectric permeability of the retarding medium is investigated. Three possible operating regions of a Cherenkov radiator are recommended and basic considerations are presented on the selection of the optimum construction of the radiator for each of these three regions. *(11F, 20R)*

—mwj—

N. P. Kerzhentseva:

WAVEGUIDE BEND OF VARIABLE CURVATURE.

pp. 733-739

A bend in multimode waveguides is a source of considerable losses by conversion into undesirable kinds of modes. The problem is solved of diminishing these losses by creating a bend whose curvature varies according to a definite law along its length. A logical form of bend is found which will guarantee least amplitude of parasitic modes in the maximum frequency band for a given bend length. A bend of such configuration for the H_{01} mode is analyzed. Tolerances are determined for the reproduction of the shap of the curvature. *(4F, 7R,*

—mwj—

A. L. Fel'dshtein, L. R. Iavich:

ON THE DESIGN OF STEP JUNCTIONS WITH MAXIMALLY-FLAT CHARACTERISTIC.

pp. 762-770

A method is proposed to design two-step and three-step junctions with maximally-flat characteristic. The relations are tabulated for the drops in the wave impedances between 1.2 - 9.2 limits. Experimental results are presented. The computations are illustrated by the example of matching waveguides of identical width and different height. Junctions in coaxial lines can be computed in an analogous manner. *(9F, 2T, 3R*

—mwj—

V. Gusa, B. Kvasil:

MEASUREMENT OF THE CONDUCTIVITY OF SEMICONDUCTORS IN THE CENTIMETER WAVE BAND.

pp. 796-805

A contactless method of measuring th electrical conductivity of semiconductors particularly of Ge and Si, is described The method can be used effectively t classify the purity of Si, refined by chemical method. The material shoul have the shape of a needle. The measurements are made by determining the Q of cavity resonator without and with th sample. *(5F, 1T, 4R*

—mwj—

RADIOTEKHNIKA I ELEKTRONIKA, 5(7) (1960)

V. A. Solntsev, A. S. Tager:

EXCITATION OF WAVEGUIDE SYSTEMS BY AN ELECTRON STREAM WITH GIVEN MODULATION.

pp. 1100-1111

The problem is solved of the excitatio of a periodic waveguide system with losse due to current having the form of a non monochromatic travelling wave whose amplitude and velocity vary periodicall along the system. The general relation obtained are used to analyze the Cherenkov and Doppler effects for a sequence o electron bunches moving with variabl velocity in a waveguide system with arbitrary dispersion. *(4F, 6R*

—mwj—

(*Continued on page 68*)

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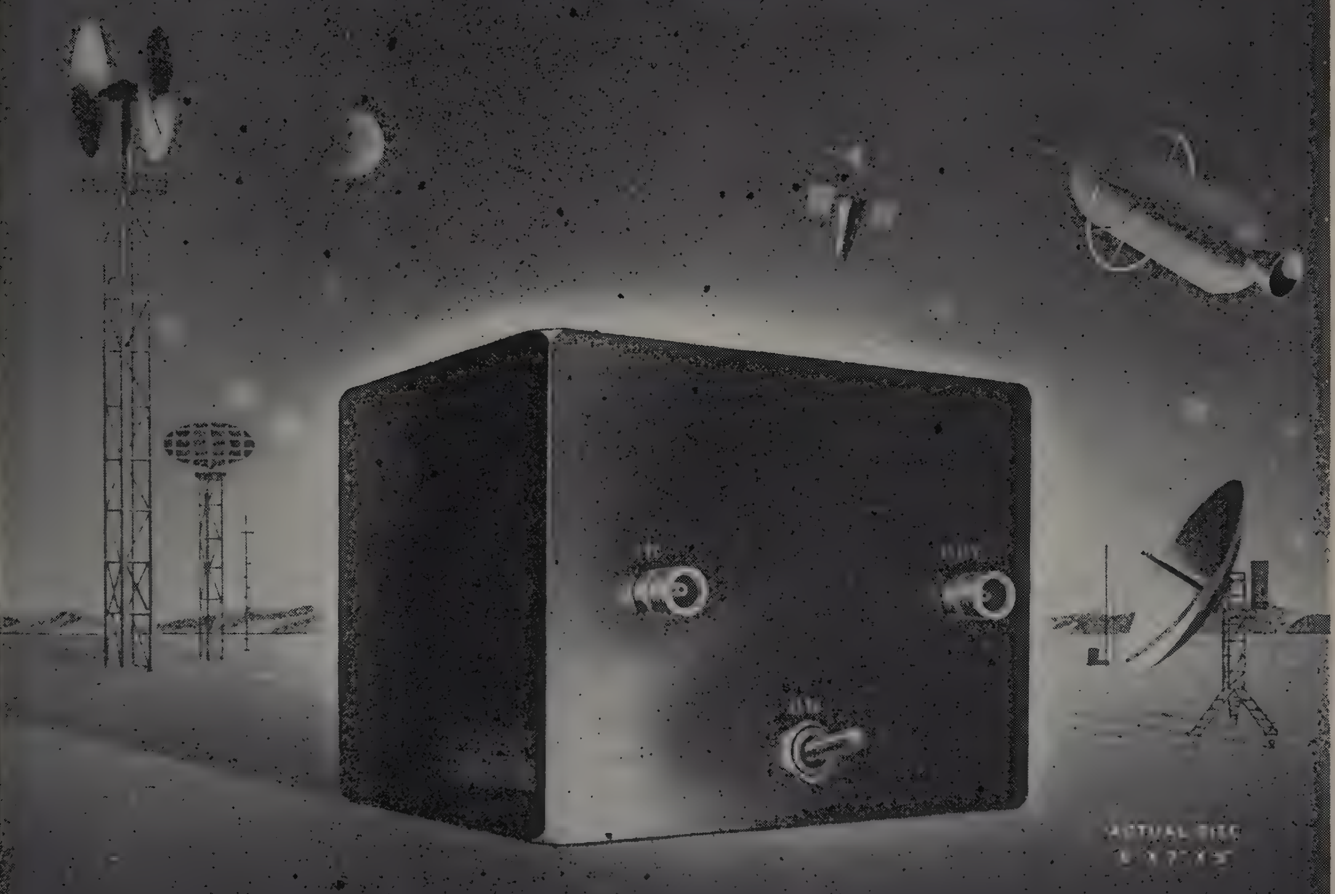

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Russian Abstracts

(*Continued from page 66*)

Wang Huan-Cho:

METHOD OF COMPUTING A DIELECTRIC INSERT TO MATCH H_{01} MODES IN THE JUNCTION BETWEEN TWO CIRCULAR WAVEGUIDES.

pp. 1072-1077

Wave numbers of the H_{01} and H_{02} modes are found in a waveguide of circular cross-section with a dielectric rod. The shape of the dielectric insert in the conical junction between two waveguides of different radius is determined for which the total coupling coefficient between the modes is zero. *(6F, 3R)*

—*mwj*—

D. I. Mirovitskii, G. G. Valeev:

SURFACE WAVE DIRECTIONAL COUPLERS.

pp. 1078-1084

Results are presented of an experimental investigation of a new kind of directional coupler, which is two intersecting surface-wave transmission-lines. Despite their structural simplicity, such couplers have high directivity (more than 45 db) and low transitional attenuation in a wide frequency band. *(13F, 12R)*

—*mwj*—

RADIOTEKHNIKA I ELEKTRONIKA, 5(6) (1960)

V. I. Zimina:

EXPERIMENTAL INVESTIGATION OF ELECTROMAGNETIC WAVE PROPAGATION ALONG A CYLINDER OF IONIZED GAS.

pp. 938-942

An experimental investigation is described of electromagnetic decimeter wave propagation along cylindrical tubes filled with an ionized gas.

The dependences of the phase velocity, attenuation of the modes being propagated, the retardation coefficient and the magnitude of the critical electrical permeability on the electron concentration are analyzed. *(4F, 2R)*

—*mwj*—

Iu. V. Anismiova, G. A. Bernashevskii, A. N. Vystavkin, L. G. Lomidze:

MILLIMETER-BAND INVESTIGATION OF WAVEGUIDE RADIATORS EXCITED BY A RELATIVISTIC ELECTRON STREAM.

pp. 969-980

A theoretical computation is made of various waveguide radiators using relativistic bunched electron beams. The radiation in a smooth waveguide by a magnetic ondulator and by a waveguide filled with a dielectric (Cherenkov effect) i computed in the prescribed currents approximation. Results are presented of a experimental investigation of variou radiators in the millimeter band. A linea accelerator operating in the 10 cm ban with 0.5 - 5 MeV output energy is th source of the bunched beam. The radiatio spectrum consisted of separate lines at frequencies which are multiples of th beam-bunching frequency. The radiatio power achieved 10 - 100 mW at the 10 12th harmonics (8 - 10 mm wavelength and as the wavelength was shortene from 10-2 mm diminished with an averag velocity of approximately 1 db upo transition into each successive harmonic. *(11F, 1T, 16R*

—*mwj*—

RADIOTEKHNIKA I ELEKTRONIKA, 5(9) (1960)

L. P. Lisovskii:

EXPERIMENTAL STUDY OF A BACKWARD-WAVE TUBE WITH INHOMOGENEOUS RETARDING SYSTEM.

pp. 1442-1447

Results are explained of an investigation of the properties of a backward-wav tube with a retarding system in the form of a double ridge, where the height o the teeth varies smoothly along the longitudinal axis. *(6F*

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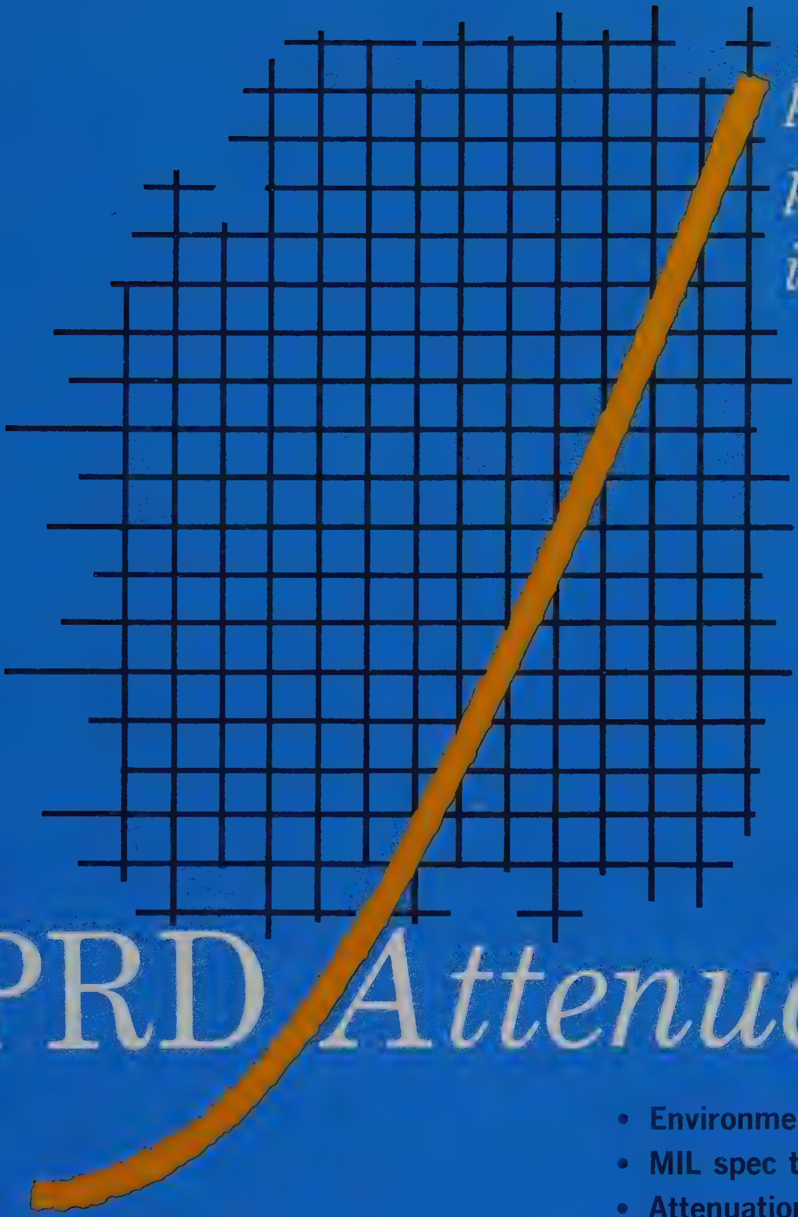

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PRD *Attenuators*

- **Environmental stability**
- **MIL spec types, ruggedized**
- **Attenuation to 70 db**
- **Systems application**
- **Accuracies to ± 0.2 db**
- **Insertion losses as low as 0.5 db**
- **VSWR as low as 1.1**
- **Over 100 catalog items**
  Waveguide and Coaxial
  Fixed and Variable

PRD
ELECTRONICS, INC.
A Subsidiary of Harris-Intertype Corporation
Formerly, Polytechnic Research & Development Co., Inc.
HARRIS INTERTYPE CORPORATION
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VARIABLE TYPES

PRD

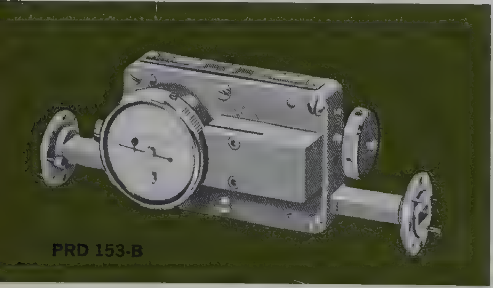
PRD 196-DS

MIL Spec Types, Ruggedized

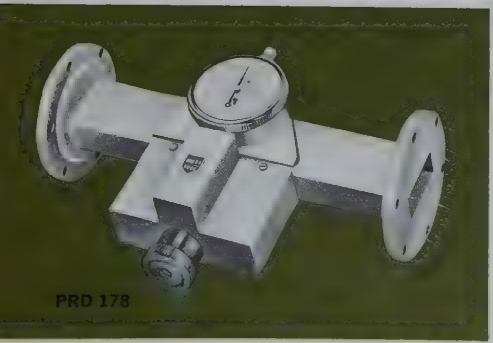
Developed, under special order, are a series of one-watt X-Band ruggedized variable waveguide attenuators ranging in maximum attenuation value up to 70 db. These include the 195-CP series, 196-DP series and 196-DS series. Many of these attenuators are relatively frequency insensitive and have been designed for servo-driven applications. Most of these units fulfill all of the requirements specified for Military applications, including airborne and ground support operations. Typical environmental specifications include:

- Operation at altitudes to 10,000 feet
- Operation over the temperature range from −40°C to +55°C
- Operation at humidities up to 100% relative
- Operation in a salt sea atmosphere... 50 hours at 20% and 95°F
- Withstand shock and vibration as specified in MIL-T-945A

All of these units are available in a variety of special finishes to meet customer requirements.



PRD 153-B



PRD 178

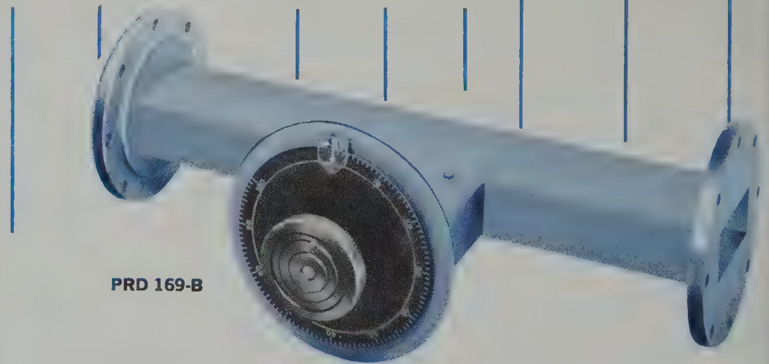
Precision Dial Types

The single turn knob of these instruments provides unusual ease of a ment. PRD precision dial attenuators are excellent as repeatable isolatio level set devices. On special order, dials will be calibrated to read direc decibels of attenuation . . . an attractive feature for designing into sy

Type No.	Equivalent Waveguide Type	Waveguide Dimensions (inches)	Frequency Range (kmc/sec)	Attenuation Range (db)	Maximum VSWR	Maximum Insertion Loss (db)	CALIBRATION ACCURACY‡ (db)		Maximu Average Power Dissipate (watts)
							With Curve	Engraved Dial	
169-B	RG-49/U	2 x 1	3.95 to 5.85	45	1.15	0.5	±0.3	±0.5	1
174-B	RG-48/U	3 x 1½	2.6 to 3.5*	40	1.15	0.5	±0.3	±0.5	1
177-B	RG-50/U	1½ x ¾	5.4 to 7.2*	45	1.15	0.5	±0.3	±0.5	1
184-B	RG-51/U	1¼ x ⅝	7.0 to 10.0	40	1.15	0.5	±0.3	±0.5	1
187-B	RG-107/U	0.622 x 0.311 I.D.	12.4 to 18.0	45	1.15	0.5	±0.4	±0.6	1
196-C	RG-52/U	1 x ½	8.2 to 12.4	45	1.15	0.5	±0.3	±0.5	1
196-D	RG-52/U	1 x ½	8.5 to 9.6*	70	1.15	1.0	±0.6 to 50 db ±1 db above 50 db	±1.0 to 50 db ±1.5 above 50 db	1
1177	RG-50/U	1½ x ¾	5.4 to 5.9	70	1.15	1.0	±0.3 to 40 db ±1.0 above 40 db	±0.6 to 40 db ±1.5 above 40 db	1

‡Calibrations at any frequency in the appropriate waveguide band are provided upon Special Order only.

*The frequency range of the PRD 174-B, 196-D and 177-B may be extended to provide full coverage of their respective waveguid possible sacrifice in maximum attenuation.



PRD 169-B

Precision Gauge Types

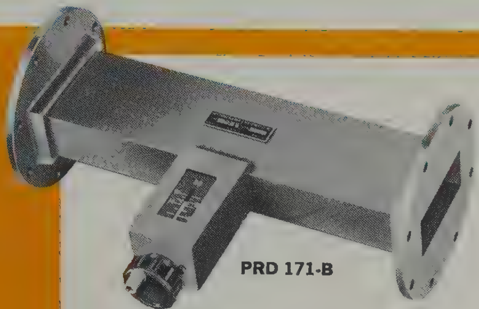
These are designed to give extremely accurate measurements of attenuation...to act as calibration standards and test instruments in a variety of systems. They have excellent environmental stability and are to all practical purposes unaffected by years of use.

Type No.	Equivalent Waveguide Type	Waveguide Dimensions (inches)	Frequency Range (kmc/sec)	Attenuation Range (db)	Maximum VSWR	Maximum Insertion Loss (db)	Calibration Frequency‡ (kmc/sec)	Calibration Accuracy (db)	Maximum Average Power (watts)	Flange Type
175-B	RG-48/U	3 x 1½	2.6 to 3.5*	40	1.15	0.5	3.0	±0.2	1	UG-53/U
170-B	RG-49/U	2 x 1	3.95 to 5.85	45	1.15	0.5	4.9	±0.2	1	UG-149/U
178-B	RG-50/U	1½ x ¾	5.4 to 7.2*	45	1.15	0.5	6.8	±0.2	1	UG-344/U
185-B	RG-51/U	1¼ x ⅝	7.0 to 10.0	40	1.15	0.5	8.6	±0.2	1	UG-51/U
195-B	RG-52/U	1 x ½	8.2 to 12.4	50	1.15	0.5	9.6	±0.2	1	UG-39/U
195-D	RG-52/U	1 x ½	8.5 to 9.6*	70	1.15	0.5	9.0	±1.0	1	UG-39/U
188-B	RG-107/U	0.622 x 0.311 I.D.	12.4 to 18.0	40	1.15	0.5	15.0	±0.2	1	UG-419/U
153-B	RG-66/U	0.420 x 0.170 I.D.	18.0 to 26.5	35	1.10	0.5	24.0	±0.2	1	UG-425/U
153-BF1	RG-66/U	0.420 x 0.170 I.D.	18.0 to 26.5	35	1.10	0.5	24.0	±0.2	1	UG-595/U
192-A	RG-96/U	0.280 x 0.140 I.D.	26.5 to 40.0	40	1.10	0.5	35.0	±0.2	1	UG-381/U
192-AF1	RG-96/U	0.280 x 0.140 I.D.	26.5 to 40.0	40	1.10	0.5	35.0	±0.2	1	UG-599/U

‡Calibrations at frequencies other than those shown above are available upon special order.

*The frequency range of the PRD 175-B, 195-D and 178-B may be extended to provide full coverage of their respective waveguide bands with possible sacrifice in maximum attenuation.

Vaveguide Attenuators



PRD 171-B

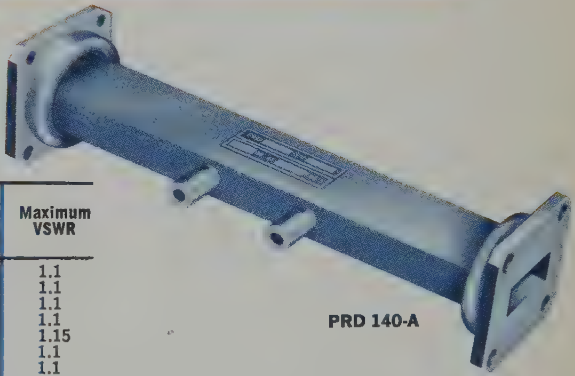
Level Set Types

PRD level set attenuators feature a ruggedized vane which is strongly resistant to shock and moisture. These instruments are excellent for vernier level adjustments and as padding devices for experimental, production, and field set-ups as well as permanent systems components.

Type No.	Frequency Range (kmc/sec)	Waveguide Type	Waveguide Dimensions (inches)	Flange Type	Maximum Attenuation (db)	Maximum VSWR	Average Power Dissipation (watts)	Overall Length (inches)
171-A	2.6 - 3.95	RG-48/U	3 x 1½	UG-53/U	20	1.15	1	8¾
171-B	2.6 - 3.95	RG-48/U	3 x 1½	UG-53/U	40	1.15	1	12
162-A	3.95- 5.85	RG-49/U	2 x 1	UG-149A/U	20	1.15	1	6
162-B	3.95- 5.85	RG-49/U	2 x 1	UG-149A/U	40	1.15	1	7¾
156-A	5.85- 8.2	RG-50/U	1½ x ¾	UG-344/U	20	1.15	1	5¼
156-B	5.85- 8.2	RG-50/U	1½ x ¾	UG-344/U	40	1.15	1	7¼
160-A	7.05-10	RG-51/U	1¼ x ⅝	UG-51/U	20	1.15	1	4
160-B	7.05-10	RG-51/U	1¼ x ⅝	UG-51/U	40	1.15	1	5¾
159-A	8.2 -12.4	RG-52/U	1 x ½	UG-39/U	20	1.15	1	3²¹⁄₃₂
159-B	8.2 -12.4	RG-52/U	1 x ½	UG-39/U	40	1.15	1	5
158-A	12.4 -18	RG-91/U	.622 x .311 I.D.	UG-419/U	20	1.15	1	2¹¹⁄₁₆
158-B	12.4 -18	RG-91/U	.622 x .311 I.D.	UG-419/U	40	1.15	1	3²⁷⁄₃₂
155*	18 -26.5	RG-66/U	.420 x 170 I.D.	UG-425/U	40	1.10	½	3¼
157*	26.5 -40	RG-96/U	.280 x 140 I.D.	UG-381/U	40	1.15	¼	2¼

*Available with other flanges

FIXED TYPES



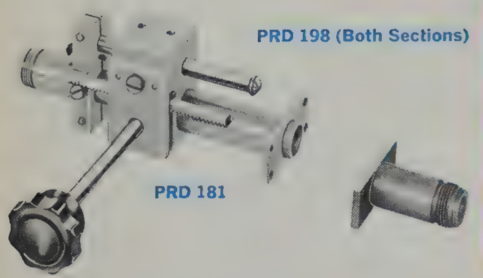
PRD 140-A

In our fixed waveguide attenuators the lossy element is adjusted to a highly accurate calibration by us and locked in position. The resultant units are useful for range extension of available power measuring equipment, power level adjustment, reduction of reflection interactions, and isolation of generators and frequency meters from the pull of a mismatched load.

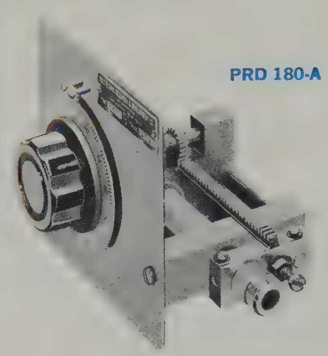
Type No.	Attenuation At Calibration Frequency (db)	Maximum Total Frequency Sensitivity (db)	Maximum VSWR
118-A	3	0.5	1.1
118-B	6	0.6	1.1
118-C	10	1.0	1.1
118-D	20	1.5	1.1
118-E	30	2.0	1.15
119-A	3	0.5	1.1
119-B	6	0.5	1.1
119-C	10	1.0	1.1
119-D	20	1.0	1.1
119-E	30	1.5	1.15
120-A	3	0.3	1.1
120-B	6	0.4	1.1
120-C	10	0.5	1.1
120-D	20	0.5	1.1
120-E	30	0.6	1.15
137-A	3	0.35	1.1
137-B	6	0.5	1.1
137-C	10	0.5	1.1
137-D	20	0.7	1.1
137-E	30	1.5	1.15
138-A	3	1.0	1.1
138-B	6	1.0	1.1
138-C	10	1.8	1.1
138-D	20	2.5	1.1
138-E	30	3.0	1.15
140-A	3	1.0	1.10
140-B	6	1.0	1.10
140-C	10	1.5	1.10
140-D	20	1.5	1.15
140-E	30	2.0	1.15
140-F	40	4.0	1.15

Type No.	Equivalent Waveguide Type	Waveguide Size (inches)	Frequency Range (kmc/sec)	Calibration Frequency (kmc/sec)	Calibration Accuracy (db)	Maximum Average Power (watts)	Insert Length (inches)	Flange Type
137	RG-48/U	3 x 1½	2.60-3.95	3.0	±0.2	1	17	UG-53/U
120	RG-49/U	2 x 1	3.95-5.85	4.9	±0.2	1	11½	UG-149A/U
119	RG-50/U	1½ x ¾	6.5-7.15	6.8	±0.2	1	8½	UG-344/U
118	RG-51/U	1¼ x ⅝	7.05-10	8.6	±0.2	1	7	UG-51/U
140	RG-52/U	1 x ½	8.2-12.4	9.6	±0.2	1	6½	UG-39/U
138	RG-107/U	.622 x .311 I.D.	12.4-18.0	15.0	±0.2	1	4	UG-419/U

Coaxial Attenuators


PRD 198 (Both Sections)

PRD 181


PRD 180-A

VARIABLE CUTOFF TYPES

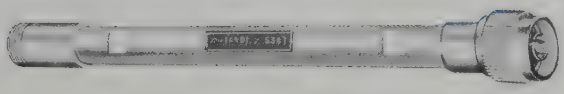
Our variable cutoff attenuators offer a minimum size and maximum range of attenuation, for applications where initial insertion losses can be high. PRD 180 is designed to couple 1 x ½ waveguide to coaxial in the frequency range of 8.2 to 10 kmc. PRD 198 is for coaxial systems between 1 and 4 kmc.

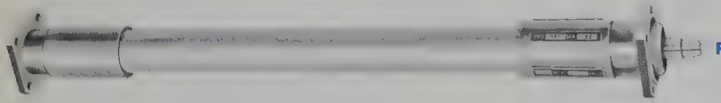
TYPE NO.	FREQUENCY RANGE (kmc/sec)	ATTENUATION RANGE (db)	INSERTION LOSS* (db)	LINEAR SLOPE	CUTOFF TUBE DIAMETER (inches)	f_c (kmc/sec)
180-A	8.2 to 10	100	3 at 9 kmc/sec	1 db per division	0.338	20.45
181	1 to 4	100	—	0.36 db per degree	0.500	13.83
198	1 to 4	100	16 at 3 kmc/sec	0.36 db per degree	0.500	13.83

*Factory adjustment.

TYPE NO.	EQUIVALENT WAVEGUIDE TYPE	WAVEGUIDE SIZE (inches)	COAXIAL LINE SIZE (inches)	FLANGE TYPE	COAXIAL CONNECTOR	OVERALL CLOSED LENGTH (inches)	TRAVEL (inches)
180-A	RG-52/U	1 x ½	⅜	UG-39/U	Type N Jack	6 11/32	1⅛
181	—	—	⅜	—	Type N Jack	4 7/32	1 9/16
198	—	—	⅜	—	Two Type N Jacks	5 17/32	1 9/16

PRD 1100


PRD 130


PRD 136

FIXED TYPES

These fixed coaxial pads offer highly accurate attenuations for 50 ohm coaxial circuits. Applications include adjustment of power level, extension of the range of available power measuring equipment, reduction of reflection interactions, and isolation of generators and frequency meters from pulling effects of mismatched loads.

TYPE NO.	COAXIAL LINE SIZE (inches)	FREQUENCY RANGE (kmc/sec)	STANDARD CALIBRATION FREQUENCY (kmc/sec)	CALIBRATION ACCURACY (db)	MAXIMUM AVERAGE POWER DISSIPATED (watts)	CONNECTORS	INSERTION LENGTH
130	⅜	2.0 to 10*	4.0	±0.2	1	UG-21( )/U UG-23( )/U	7 29/32
130-C1	⅜	2.0 to 10*	4.0	±0.2	1	UG-573/U UG-572/U	7 25/64
130-C2	⅜	2.0 to 10*	4.0	±0.2	1	UG-572/U UG-572/U	7¾
136	⅞	1.0 to 4.0	1.2	±0.2	1	UG-45/U UG-46/U	13 7/16
1100	⅜	0 to 4.0	1.2	±0.2	1	UG-21( )/U UG-23( )/U	2⅛

*PRD 130-D and 130-DC series are rated from 2.4 to 10.0 kmc/sec

Related instruments not shown here but described in our general catalog and readily available include rotary vanes, shielded uncalibrated variable attenuators, coaxial terminations, fixed waveguide terminations, sliding waveguide terminations, ferrite isolators, sliding shorts, and standard precision mismatches.

These are but a few of the units in the long line of precision microwave test instruments from PRD. If you don't have a copy of the giant PRD catalog, contact your nearest engineering representative or write PRD Electronics, Inc., 202 Tillary Street, Brooklyn 1, New York.

PRD
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(*Continued from page 63*)

NEW LOCKHEED POST FILLED BY ANSOFF

Dr. H. Igor Ansoff, vice president of Lockheed Electronics Co., Plainfield, N. J., has been appointed to the new post of General Manager of the company's Information Technology Division in Metuchen, N. J.

D. F. Sanders, Lockheed Electronics president, said Dr. Ansoff's appointment is a major organizational step in a move to establish the company in the industrial data processing and special purpose computer market.

Ansoff formerly directed Lockheed Aircraft Corporation's diversification program leading to the acquisition of Stavid Engineering, Inc. and the formation of Lockheed Electronics Co. in 1959. He became vice president, plans and programs, of the Lockheed subsidiary in 1960.

Before joining Lockheed Dr. Ansoff was with the RAND Corp. for eight years, serving as project officer and conducting a series of technical studies on national defense problems.

—*mwj*—

TI DIVISION FORMS NEW DEPARTMENT

The Radar and Microwave Products Department, recently established by Texas Instruments in its Apparatus division, Dallas, Texas now offers complete capabilities in microwave devices, components, and accessories for both military and non-military applications.

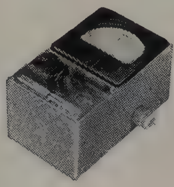
Headed by K. P. Dowell, the new department was organized to supply specialized radar and microwave assemblies and components to producers of systems. Components utilizing new solid state technologies are produced in both standard and custom-engineered designs.

Among the microwave products that have been developed are a complete line of broadband, low-noise varactor diode parametric amplifiers and accessories to cover frequency ranges from L to K_u band, solid state microwave signal sources with outputs ranging from 10 Mc to 20 kMc, and diode harmonic generators for frequencies to 20 kMc. In addition, the new department has made available rotary joints, filters, traps, mixers, preselectors and IF preamplifiers, complete low-noise receivers, tunnel diode circuits, circulators and other ferrite devices.

—*mwj*—

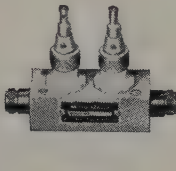
DIRECTIONAL COUPLERS • RF LOAD RESISTORS
COAXIAL TUNERS • RF WATTMETERS • VSWR METERS

MicroMatch® RF Power and VSWR measuring instruments are rugged and accurate in both field and laboratory use. The patented circuit produces an output essentially *independent of frequency*. Over 3800 models of coupler units available. MICRO-MATCH instruments meet highest government and commercial standards, combine highest quality with low cost.



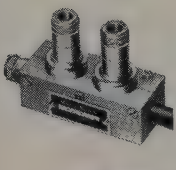
RF POWER and VSWR Instruments

Model No.	Frequency Range (mcs.)	Power Range Incident & Reflected (watts)	RF Connectors and Impedance
263	0.5 - 225	0 - 10; 100; 1000	Type N* 52 ohms
706N	28 - 2000	0 - 400	Type N* 52 ohms
711N	25 - 1000	0 - 30; 75; 300	N plus 83-1R Adapters
712N	25 - 1000	0 - 2.5; 5; 10	N plus 83-1R Adapters
722N	1000 - 3000	0 - 4	Type N 52 ohms
723N	1000 - 3000	0 - 12	Type N 52 ohms
405B8	28 - 2000	0 - 4000	1⅝" Flange 51.5 ohms
445A10	20 - 2000	0 - 40,000	3⅛" Flange 50.0 ohms



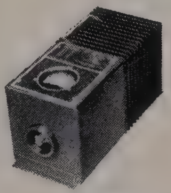
DC OUTPUT DIRECTIONAL COUPLERS

Model No.	Frequency Range (mcs.)	Power Range Incident & Reflected (watts)	RF Connectors and Impedance
576N1	42 - 2000	1.2	Type N* 52 ohms
576N6	28 - 2000	0 - 400	Type N* 52 ohms
596N2	1000 - 3000	0 - 4	Type N 52 ohms
596N3	1000 - 3000	0 - 12	Type N 52 ohms
402B8	28 - 2000	0 - 4000	1⅝" Flange 51.5 ohms
442A9	28 - 2000	0 - 12,000	3⅛" Flange 50.0 ohms



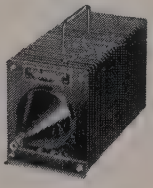
RF OUTPUT DIRECTIONAL COUPLERS

Model No.	Frequency Range (mcs.)	Coupling Attenuation	RF Connectors and Impedance
313N3	300 - 2000	30 db	Type N* 52 ohms
313N5	60 - 2000	50 db	Type N* 52 ohms
442A40	200 - 1000	40 db	3⅛" Flange 50.0 ohms



ABSORPTION TYPE RF WATTMETERS

Model No.	Frequency Range (mcs.)	Power Range (watts)	RF Connectors and Impedance
621N	1 to over 1000	0 - 120 milliwatts	Type N* 52 ohms
625C5	50 - 1000	0 - 120	Type C 50 ohms
651N	25 - 1000	0 - 25; 100; 500	Type N 52 ohms
611A7	50 - 1000	0 - 1200	3⅛" Flange 50 ohms
612A	44 - 1000	0 - 6000	3⅛" Flange 50 ohms

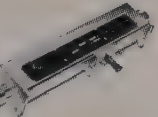


RF LOAD RESISTORS

Model No.	Frequency Range (mcs.)	RF Power Dissipation (watts)	RF Connectors and Impedance
603N	3000	20 (air cooled)	Type N 52 ohms
633N	3000	50 (air cooled)	Type N* 52 ohms
636N	3000	600 (air cooled)	Type N* 52 ohms
638A	2000	6000 (water cooled)	3⅛" Flange 50.0 ohms

CALORIMETRIC TYPE Primary Standard of RF Power

Model No.	Frequency Range (mcs.)	Power Range	RF Connectors and Impedance
641N	0 - 3000	0 - 3; 10; 30; 100; 300	Type N 52 ohms



COAXIAL LINE TUNERS

Model No.	Frequency Range (mcs.)	Range of Correction	RF Connectors and Impedance
151N	200 - 1000	Tunes a load with a VSWR of 2.00 max. down to a VSWR of 1.00	Type N 50 ohms
152N	500 - 4000		Type N 50 ohms

*Also available with UHF, C and BNC Connectors

For more information, write:

M.C. Jones

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185 N. MAIN STREET, BRISTOL, CONN.
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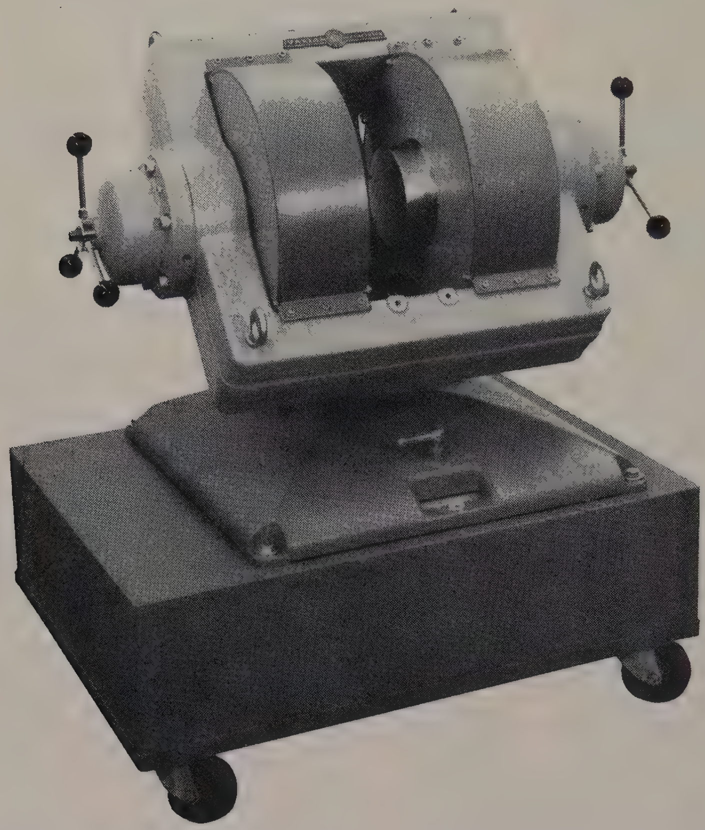
ADJUSTABLE AIR GAP/ROTATABLE 6″ LABORATORY MAGNET

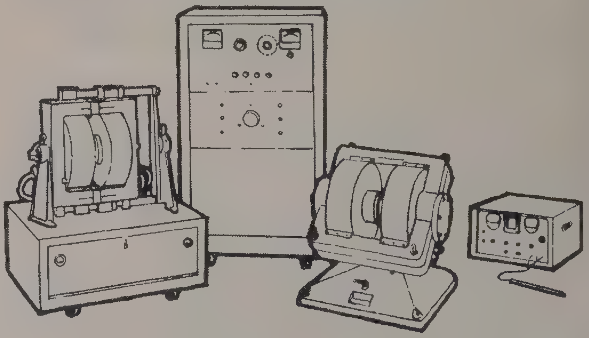
Rotate **and** adjust the air gap easily and precisely



Continuously adjust air gap widths from zero to 6″, as well as rotate the magnetic field over a 200° arc with reference to the vertical, using the new Varian V-4007-2 laboratory magnet. Field homogeneity reproduces accurately after gap adjustment, since the gap-adjusting assembly maintains precise axial alignment and parallelism throughout total pole cap travel. Field strength and homogeneity can be quickly verified using the Varian F-8 Fluxmeter. Traditional Varian design foresight makes the gap-adjusting assembly compatible for fitting to all Varian 6″ rotatable magnets presently in use. And, of course, the new V-4007-2 can be converted to the V-4007-1 configuration when the homogeneity of this most rigid magnet is a requirement.

A complete magnet family with accessories

Varian's V-4007-1 rotatable and V-4007-fixed-azimuth 6″ magnets complement the new V-4007-2 to provide the most complete line of 6″ laboratory magnets available. Select the system that precisely matches your field-volume/strength/homogeneity needs from these three versatile 6″ types, and Varian's 4″ adjustable-gap, 12″ adjustable-yoke, 12″ rotator and new 22″ high-field laboratory magnets. Matching regulated power supplies, a wide range of pole cap options, a fluxmeter-control unit, rolling and rotating bases, support tables and other accessories, plus a world-wide service engineering organization, make Varian the logical choice for all your magnet needs.



V-4007 6″ magnet yoke is adjustable about the horizontal axis. Air gap width is adjusted with precision yoke-separating spacer blocks.

V-2200A (shown), **V-2100B** power supplies furnish precisely regulated power to Varian's 6″ and 12″ magnets. Matching regulated power supplies are available for the complete Varian magnet line.

V-4007-1 6″ magnet rotates around the vertical axis and uses pole caps of various thicknesses for air gap adjustment.

The **F-8 Fluxmeter** provides precise measurement and/or control of magnetic fields as an accessory to Varian magnet systems and readily adapts to other systems.

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After his discharge, Mr. Epis attended the University of California. He received the BS and MS degrees in electrical engineering in 1950 and 1952, respectively, and became a part-time research assistant at the University of California Antenna Laboratory during his graduate years.

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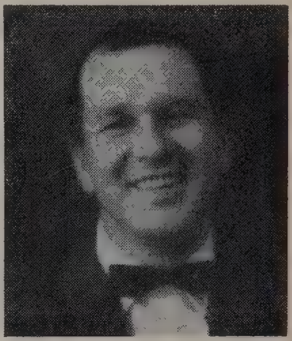

TADASU KAWANO was born in Hiroshima, Japan, on June 7, 1917. He received the BE degree in electrical engineering from the Tokyo Institute of Technology in 1941, where he served as assistant from 1941 to 1943, did graduate work from 1944 to 1945 and was appointed instructor in 1946. He was then transferred to Hiroshima University, where in 1951 he was appointed assistant professor and in 1955, professor. In 1959 he received the PhD degree in electrical engineering from the Tokyo Institute of Technology.

Since 1943 he has been engaged in research on the generation of high-power damped microwaves by spark discharges, their applications to broadband microwave measurements, measurements on microwave ferrite devices, parametric amplifiers and antenna impedances.

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LEO YOUNG was born in Vienna, Austria, on August 18, 1926. He was educated at St. John's College, Cambridge, England, obtaining MA degrees in Mathematics in 1945, and Physics in 1947.

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Dr. Young is a member of Sigma Xi, IEE, AIEE, and a senior member of IRE.

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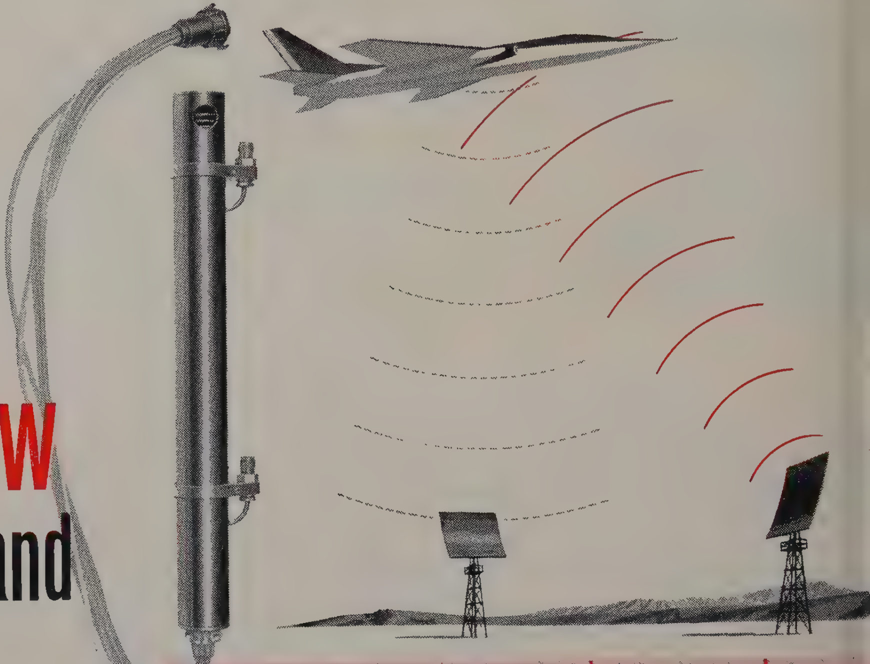

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Helix Current	—	7	—	3.2	mAdc
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CHARACTERISTICS AND APPLICATIONS OF MICROWAVE SPARK OSCILLATORS

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I. Introduction

The progress of microwave tubes has made microwave spark oscillators useless in the engineering field, though the latter had been studied earnestly by many workers in the past half century.

The spark waves radiating from the spark dipole immersed in kerosene, however, seem to have promise of being applied to some microwave measurements in the form of either heavily damped waves or weakly damped waves, for they have the advantages of large peak power, flat spectrum and constancy of intensity with time.

Reviews of past researches into spark generators have recently been given by M. H. N. Potok[1] and J. L. Farrands.[2]

The spark oscillators of the moving particle type have been investigated by F. R. Dickey, Jr.,[3] J. T. Tykociner[4] and D. F. Holshouser[5] with the view of obtaining strong millimeter radiation. However, their results were pessimistic as far as power output is concerned.

The mechanism of spark generation of microwaves and the applications of spark generators to microwave measurements seem to have remained relatively unexplored.

The purpose of the present paper is to describe the characteristics of the spark oscillator and its applications to some microwave measurements.

II. Construction and Characteristics of Spark Oscillators

(A) *Construction*

Two kinds of spark dipoles are illustrated in Figure 1. The first type is made of a carbon film resistor whose metallic cap on one side is removed and a small piece of tungsten rod is inserted as one half of a dipole.

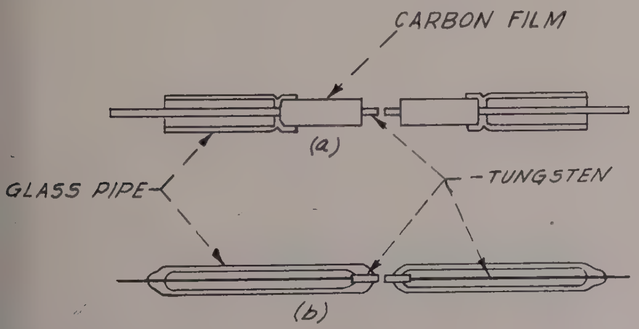

Figure 1 — Spark dipoles. (a) carbon film resistor type, (b) Right type.

The second type is the Righi dipole. These tungsten dipoles are installed in a waveguide as shown in Figure 2, and 5000 volts at 60 cycles AC is supplied through a series resistances of 2 meg-ohms.

As the oscillator is immersed in kerosene, electric sparks in oil pass between the tungsten pieces. Most of the microwave energy radiated from the dipole is propagated through the main waveguide, and a fraction of the energy leaks out along the dipole leads. The leakage energy is picked up by an electromagnetic horn and is used as a reference signal for a coherent detector. The reference signal may be taken from the main waveguide.

(B) *Characteristics*

(i) *Noise Temperature Ratio*

The noise temperature ratio,[6] i.e., the microwave power per unit bandwidth of a dipole of 19 mm length measured by an adjustable filter, a waveguide thermistor mount and an adjustable attenuator, is illustrated in Figure 3. It is seen that the half value width of the power density curve is 1.7 kMc.

Figure 4 shows measured noise temperature ratios of the spark oscillators whose dipole lengths are 2, 7 and 19 mm respectively. The noise temperature ratio decreases inversely proportional to about the third power of frequency.

(ii) *Spark Recurrence Frequency* (f_r)

The arrangement for photographic studies of spark oscillators is shown in Figure 5, and one of the oscillograms obtained is shown in Figure 6. The intermittent spark discharges of several megacycles are perceived to have occurred.

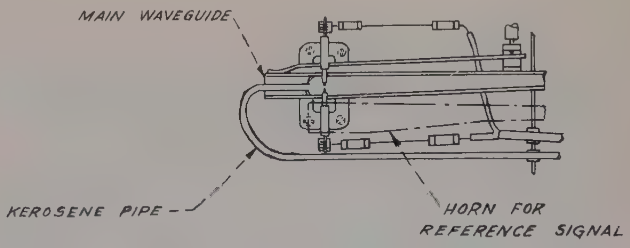

Figure 2 — Construction of spark oscillator for frequency range of 24 kMc.

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* *Reprinted from "Memoirs of the Faculty of Engineering, Hiroshima University, Vol. 1, No. 3," February, 1960.*

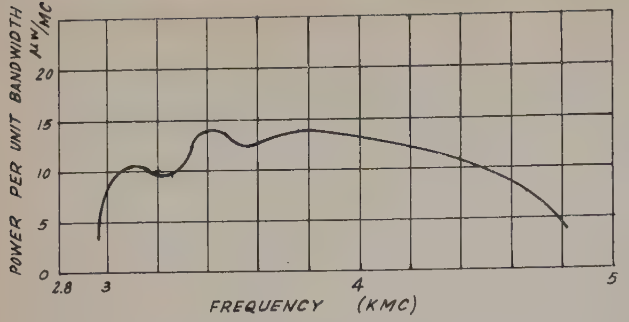

Figure 3 — Power spectrum of the spark wave radiated from a 19 mm length dipole.

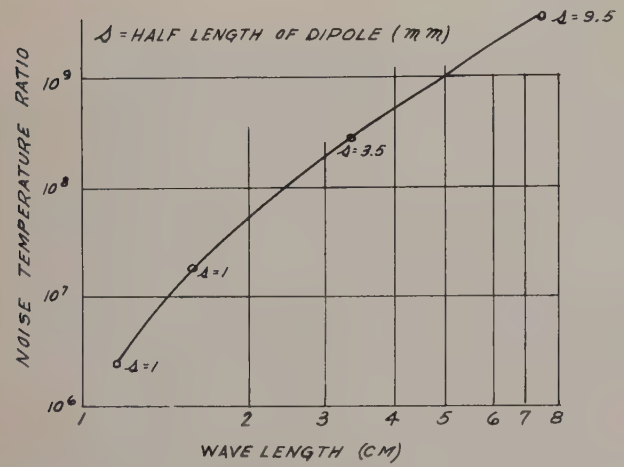

Figure 4 — Noise temperature ratio of the spark oscillators for various wavelength range.

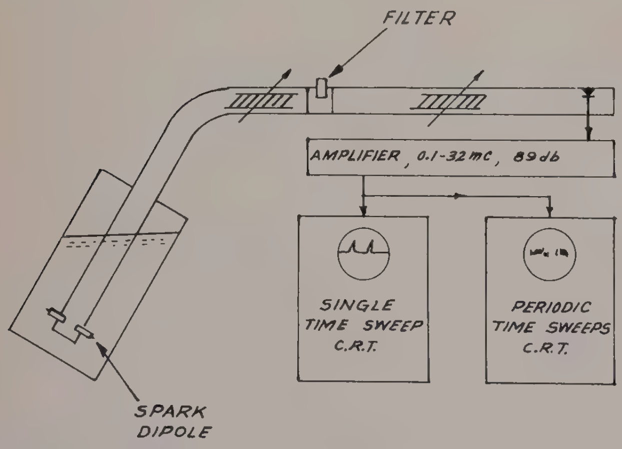
FILTER
AMPLIFIER, 0.1-32 mc, 89 db
SINGLE TIME SWEEP C.R.T.
PERIODIC TIME SWEEPS C.R.T.
SPARK DIPOLE

Figure 5 — Arrangement for photographic studies of spark oscillators.

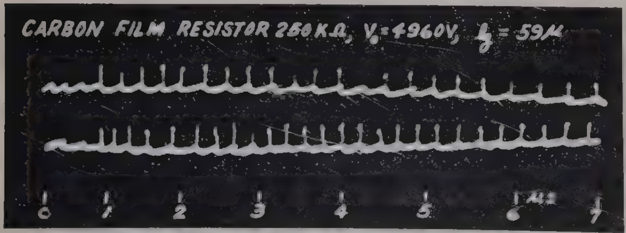
CARBON FILM RESISTOR 250 KΩ, V_0=4960V, l_g = 59μ
0
1
2
3
4
5
6
7

Figure 6 — Oscillograms of spark waves rectified by a crystal detector.

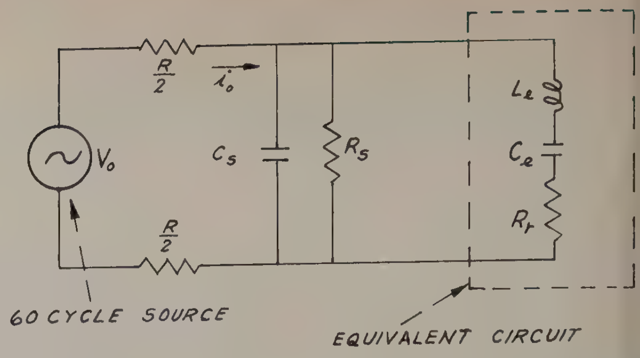
$\frac{R}{2}$
i_0
V_0
C_s
R_s
$\frac{R}{2}$
L_e
C_e
R_r
60 CYCLE SOURCE
EQUIVALENT CIRCUIT

Figure 7 — Power supplying circuit and equivalent circuit of spark dipole.

Figure 7 shows the circuit supplying high voltage to a spark dipole and the equivalent circuit of the spark dipole. When the intermittent spark discharge occurs, its recurrence frequency will be given by

$$f_r = \frac{1}{(C_s+C_e)R \ \ln(V_1-V_2)/(V_0-V_1)} \qquad (1)$$

where

V_0 = instantaneous value of supply voltage
R = series resistance
R_s = resistance of spark
C_s = electrostatic capacity formed by the facing surfaces of the dipole
C_e = equivalent lumped capacity of the dipole
V_1 = sparking voltage
V_2 = stopping voltage of discharging.

The calculated values of f_r have been in close agreement with those obtained by the experiments. The measured values of f_r are shown in Figure 8 and Figure 9 From these figures it may be noticed that f_r is dependen on the series resistance R and the instantaneous source voltage V_o, while it is independent of the gap length lg.

(iii) *Energy of a Microwave Packet*

By the photographic study shown in Figure 5, th pulse height displayed on the screen of a cathode ra tube is proportional to the spark wave power per uni bandwidth at the center frequency of the filter. Therefore, the pulse height will be proportional to the energ of a microwave packet, provided that the relative powe spectrum curve does not change its shape with gap length

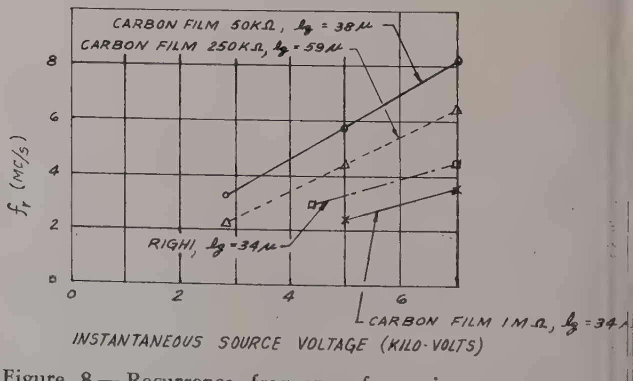

Figure 8 — Recurrence frequency f_r vs instantaneous sour voltage V_0.

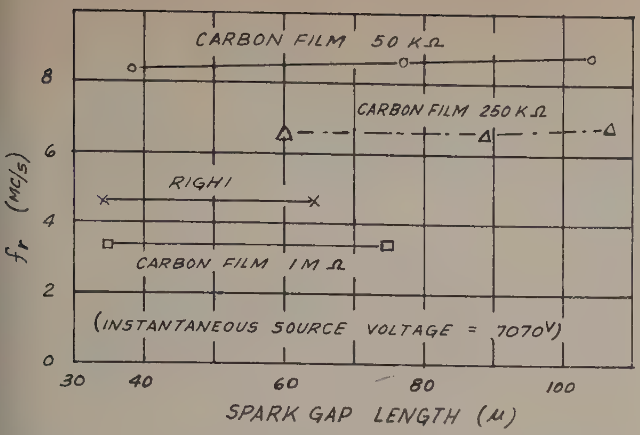

Figure 9 — Recurrence frequency f_r vs spark gap length 1g.

Experiments have confirmed that this assumption is correct.

Figure 10 and Figure 11 show the relations between relative magnitude of the energy of a microwave packet radiated from a spark dipole and gap length lg and instantaneous value V_o of the supply voltage respectively. From these figures it is concluded that the energy decreases with gap length and is almost independent of supply voltage and series resistance.

Let P_{av} = average microwave power obtained by integrating the area under a power spectrum curve

f_m = recurrence frequency of spark discharges at the crest of 60 cycles voltage

W = electromagnetic energy of one microwave packet

$2\theta_1$ = period expressed in electrical angle of 60 cycles in which the intermittent spark discharges continue, as shown in Figure 12.

Then the following equation is obtained in consideration of the fact that the recurrence frequency is proportional to the instantaneous value of 60 cycles voltage:

$$W = \frac{\pi}{2} \cdot \frac{P_{av}}{f_m \sin\theta} \qquad (2)$$

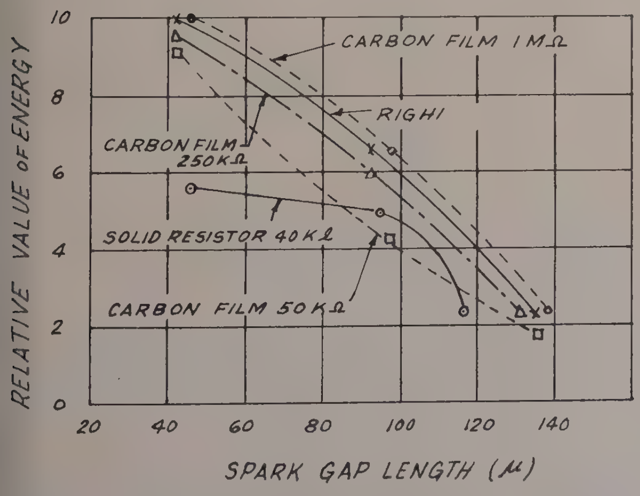

Figure 10 — Relative magnitude of the energy of a microwave packet vs gap length 1g.

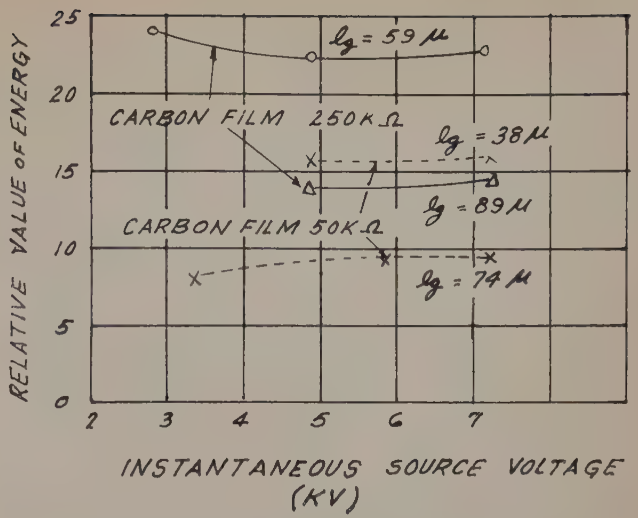

Figure 11 — Relative magnitude of the energy of a microwave packet vs instantaneous value of supply voltage.

When 5000 volts AC (r.m.s.) is supplied to a spark oscillator of 4 kMc range, we obtain

f_m = 9.1 Mc, $\sin\theta_1$ = 0.995, P_{av} = 4 mw.

Putting these data into Equation (2), we obtain

$$W = 4.16 \times 10^{-9} \text{ joule.}$$

As the electrostatic energy stored in the spark dipole is 1.69 x $^{-7}$joule, the latter is about 40 times as large as the former. In the case of a simply damped wave, peak power is expressed by

$$P_p \simeq 2f\delta W, \qquad (3)$$

where δ is the logarithmic decrement and f is the frequency.

Putting $W = 4.16 \times 10^{-9}$ joule, $\delta = 1$, $f = 4 \times 10^9$ cycles

into Equation (3), we obtain

$$P_p = 33.4 \text{ watts.}$$

Table I shows the calculated electrostatic energy stored in the spark gap and the measured electromagnetic wave energy of a microwave packet. It should be noticed that

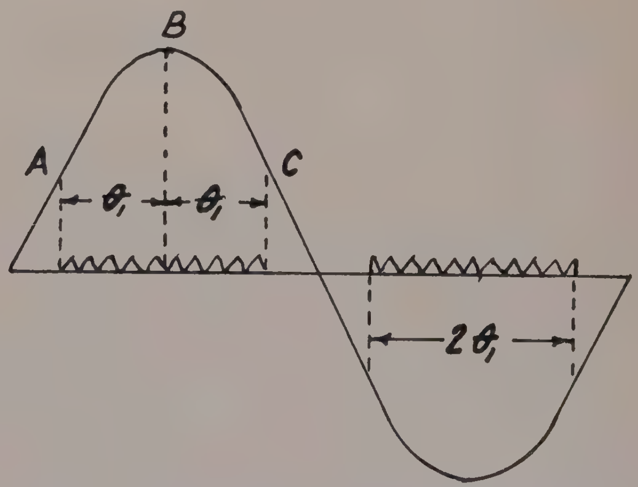

Figure 12 — Time relation between intermittent spark discharges and supply voltage.

TABLE I: Electrostatic Energy of a Spark Gap and Energy of a Wave Packet

	lg=50 (micron)	lg=100 (micron)
fr(mc) (Experimental)	6.8	7.3
fr(mc) (Theoretical)	6.8	7.6
Vi (volts)	700	1200
$1/2Cs(V_1^2-V_2^2)$ (joule)	1.7×10^{-7}	2.5×10^{-7}
W (joule)	4.2×10^{-9}	2.1×10^{-9}

$V_o=7070$(volts), $V_2 \cong O$, $R=1.4$(megohms)

if the gap length becomes twice as long, the wave energy decreases to one half despite the fact that the static energy increases by a factor of two. Probably the increase of the gap length causes the breakdown speed of the oil gap to decrease, thereby reducing the transient oscillating current of the dipole.

If the spark dipole is excited by the gap current: $i_s=kt$, the current flowing through the equivalent circuit of the dipole is

$$i=\left(\frac{\omega_1}{\omega_0}\right)^2 \frac{k}{\beta}\left[e^{-\alpha_1 t} \sin(\beta t+\theta)+\beta t-\frac{2\beta\alpha_1}{\omega_0^2}\right] \qquad (4)$$

where k=current increasing rate

$$\alpha_1=R_r/2L_e$$

$$\omega_o^2=\frac{1}{L_e}\left(\frac{1}{C_s}+\frac{1}{C_e}\right), \qquad \omega_1^2=\frac{1}{L_eC_s}$$

$$\beta^2=\omega_0^2-\alpha_1^2, \qquad \theta=\tan^{-1}\frac{2\alpha_1\beta}{\alpha_1^2-\beta^2}$$

and R_r, C_e, C_s and L_e are circuit elements such as shown in Figure 13.

The energy that one packet of the transient oscillating current consumes in the radiation resistance (R_r), is

$$W'=\int_0^{\propto} i^2R_r dt=\frac{2\pi^3R_r}{\beta\delta(\delta^2+4\pi^2)}\left(\frac{\omega_1}{\omega_0}\right)^4\left(\frac{k}{\beta}\right)^2 \qquad (5)$$

where $\delta=2\pi\alpha_1/\beta$=logarithmic decrement.

Putting $W'=4.16 \times 10^{-9}$ joule, $\delta=1$, $\beta=2\pi 4\cdot 10^9$, $R_r=73$ ohms,

$$\left(\frac{\omega_1}{\omega_0}\right)^2 \simeq \frac{C_s}{C_e} = \frac{0.43}{0.167}$$

into Equation (5), we obtain

$$k=62.2 \times 10^9 \quad \text{ampere/sec.}$$

This value of current increasing rate appears probable when compared to Fletcher's results.[7]

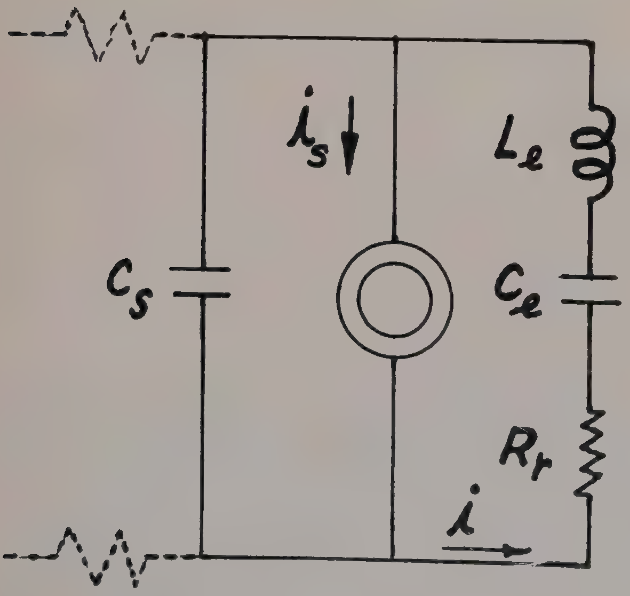

Figure 13 — Equivalent circuit of a spark dipole with a current generator at the spark gap.

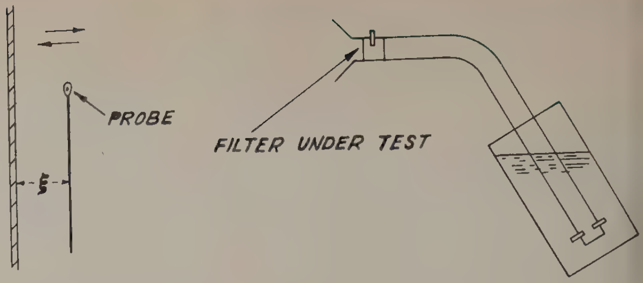

Figure 14 — Arrangement for measuring pass frequencies of a waveguide filter by standing-wave method.

III. Measurement of Higher as well as Fundamental Mode Resonant Frequencies of a Waveguide Filter

The higher as well as the fundamental mode resonant frequencies of a microwave filter can be found by the standing-wave method using ultra-wideband waves from a spark dipole. Figure 14 shows the arrangement for this measurement.

The ultra-wide-band waves radiated from a spark dipole pass through the filter under test and are projected to the plane reflecting plate in free space.

The standing-wave produced in front of the plate is detected by a vacuum thermocouple dipole. The power spectrum curve of the projected wave may be found by the Fourier transform of the standing-wave curve.[8]

Let $S(\omega)$=amplitude spectrum of the projected wave
$Y(\omega)$=absolute value of the admittance function of the probe
K=proportional constant

$$G(\omega)=K[Y(\omega)S(\omega)]^2 \qquad (6)$$

$$R(\tau)=\frac{2}{\pi}\int_0^{\infty} G(\omega)\cos\omega\tau d\omega \qquad (7)$$

$\tau=2\xi/v$
v=phase velocity of the wave,

then the standing-wave curve will be expressed by
$R(o)-R(\tau)$.

The Fourier transform of Equation (7) is

$$G(\omega)=\int_0^{\infty} R(\tau)\cos\omega\tau d\tau \qquad (8$$

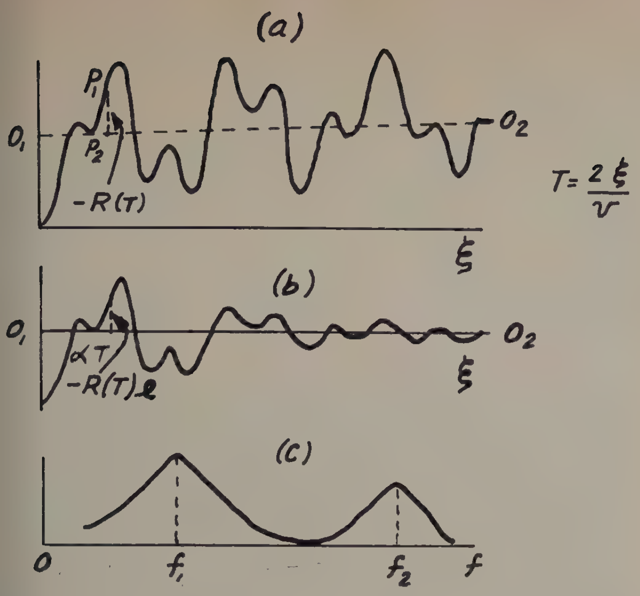

Figure 15 — (a) standing-wave curve, (b) standing-wave curve multiplied by $e^{-\alpha\tau}$, (c) power spectrum curve.

In Figure 15, the curve (a) represents the standing-wave obtained by the arrangement shown in Figure 14. The pulsating amplitude of the standing-wave curve does not decrease in the case when the incident wave has spectrum-like lines. In this case graphical integration is impossible. Let us draw a straight line O_1O_2 in order that the algebraic sum of the area surrounded by the curve and the line O_1O_2 may become zero. Take the line O_1O_2 as the base line and denote P_1P_2 as $-R(\tau)$. Draw the curve of $-R(\tau)e^{-\alpha\tau}$ as shown in Figure 15(b), where α is chosen so that $-R(\tau)e^{-\alpha\tau}$ may vanish at an appropriate distance from the origin. When the integration expressed by Equation (8) is performed graphically regarding the curve in Figure 15(b) as a new $R(\tau)$ curve, the $G(\omega)$ curve such as shown in Figure 15(c) is obtained. The frequencies and the heights at the crests of the $G(\omega)$ curve represent the pass frequencies and the power-penetrations of the waveguide filter respectively.

Figure 15 represents experimental results for a waveguide filter composed of two inductive windows of 13 mm width and one adjustable post of 5 mm thick. It is seen from this figure that the outgoing wave from the filter contains two major frequency components; 3.06 kMc and 7.9 kMc, and their power ratio is 3/2. It was also found that this higher mode resonant wave-length (3.8 cm) does not change with protruding length of the post.

IV. Measurement of VSWR of Waveguide Elements

(A) *Measuring Procedure*

If a damped wave from a spark dipole is used as a wave source for the measurement of VSWR of waveguide elements, they must be made narrow band by using a waveguide filter. The VSWR (ρ_a) obtained by using filtered spark waves becomes smaller than that obtained by using a single frequency wave where a test element is situated at a considerable distance from a standing-wave detector. This phenomenon is attributed to the fact that the filtered spark wave has a certain bandwidth. The true VSWR (ρ) may be calculated by the following equation:[9]

$$\rho^2 = \frac{\rho_b^2\,\rho_a^2 - 1}{\rho_b^2 - \rho_a^2} \tag{9}$$

Another form of Equation (9) is

$$\tanh^{-1}\frac{1}{\rho^2} = \tanh^{-1}\frac{1}{\rho_a^2} - \tanh^{-1}\frac{1}{\rho_b^2} \tag{10}$$

where ρ_b is the measured VSWR, when the waveguide is short-circuited at the element.

When the bandwidth of the filter is known, ρ can be calculated by the following equation without the knowledge of ρ_b:

$$\tanh^{-1}\frac{1}{\rho^2} = \tanh^{-1}\frac{1}{\rho_a^2} - \frac{\Delta\omega}{\omega_1}\cdot\frac{\pi l \lambda_{g1}}{\lambda_1^2} \tag{11}$$

where $\Delta\omega/2\pi = -3$ db bandwidth of the filter
l = distance between test element and probe of the slotted section
λ_1 = free space wavelength of the wave of frequency f_1
λ_{g1} = guide-wavelength of the wave of frequency f_1.

The attenuator ATT_2 must have attenuation of more than 10 db, otherwise both ρ_a^2 and ρ_b^2 would change as a function of the distance (l_o) between the test element and the filter. If we take mean value of ρ_a^2 and that of ρ_b^2 with respect to l_o, Equation (9) will give correct value of ρ. The value of ρ thus obtained agreed with that of ρ obtained by a single frequency wave of 4 kMc within 4 per cent difference at $\rho = 2.7$.

(B) *Detecting Method*

Among the detecting methods of probe signals in the case of spark waves, the two receiver coherent detection method was found to be excellent in view of simplicity and sensitivity. As shown in Figure 16, a video signal from the probe on the slotted section is amplified with a video amplifier and is applied to two diodes of a coherent detector in pushpull. The reference signal is picked up with another crystal detector located closer to the spark dipole, amplified with the same kind of video amplifier, and is applied to the two diodes of the coherent detector in parallel. The coherent detector is followed by a dc amplifier and a micro-ammeter. The recommended frequency-band of the video-amplifier is from 0.1 to 16 Mc for measurements in the 50 kMc range and from 0.1 to 1 Mc for the 4 kMc range.

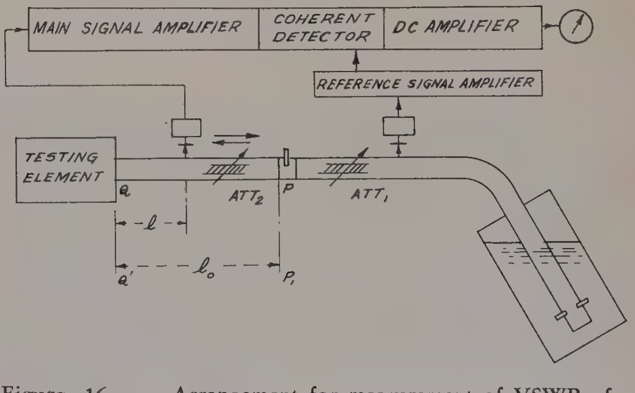

Figure 16 — Arrangement for measurement of VSWR of a waveguide element using spark wave.

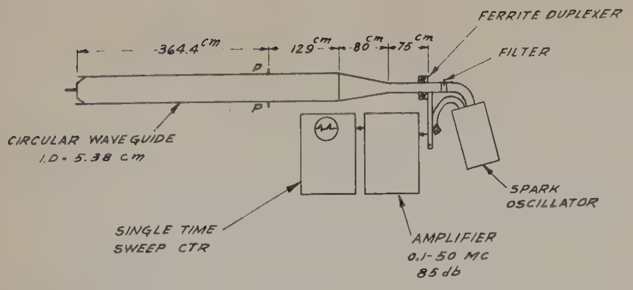

Figure 17 — Arrangement for circular waveguide pulse test with spark waves at 24 kMc range.

V. Pulse Test for Waveguides with Spark Waves

(A) *Pulse Test for Circular Waveguide at 2 kMc Range*

If there is a requirement for extremely high range resolution by waveguide investigation, the spark source with its inherently short pulses may be useful.

Figure 17 shows the apparatus for photographic investigation of the reduction of the height of the radio-frequency pulses reflected at the shorting end, when the circular waveguide has an offset at the joint P. Damped microwaves generated from a spark dipole are filtered with a waveguide filter whose center frequency is 24 kMc and whose specified bandwidth is 0.04. Being transduced to circular TE_{01} mode by a taper-type mode-transducer, they are propagated through a 53.8 mm I. D. copper circular waveguide and are reflected at the shorting end (R). They travel back through the waveguide and enter a crystal detector by means of a ferrite duplexer.

In order to display the transmitted pulses on the cathode-ray tube screen, direct waves from the spark dipole are fed to the same crystal detector through a directional coupler. The amplifier has a bandwidth from 0.1 to 50 Mc and its gain is 85 db.

Figure 18(a) represents a single time sweep oscillogram of the transmitted and the reflected pulses when there is an offset of 8 mm at the joint P. Figure 18(b) is the case of no offset. The pulses denoted by T in the oscillograms represent transmitted pulses and those denoted by R represent the pulses reflected at the shorting end of the circular guide. Figure 19 shows the relation between the height of the reflected pulse and the magnitude of the offset. It may be seen that the amount of the reflection from the offset is small.

(B) *Pulse Test for Rectangular Wave-Guide at 9 kMc Range*

Figure 20 shows the arrangement for the pulse test for a rectangular waveguide with the spark at the 9 kMc range. The single time sweep oscillograms for this case are shown in Figure 21 in which the characters T and R denote the transmitted and the reflected pulses respectively. In these figures,

f_0 = center frequency of the filter
Δf = −3 db bandwidth of the filter
v_g = group velocity of the wave of frequency f_0
C = velocity of waves in free space.

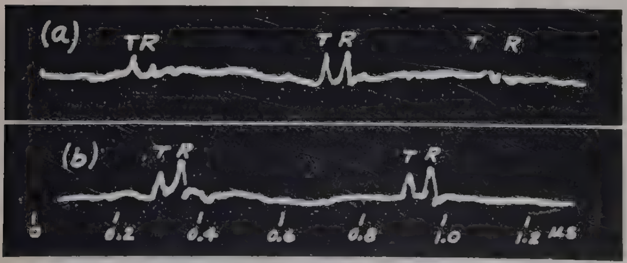

Figure 18 — Oscilloscope traces of transmitted and reflected pulses. (a) 8 mm offset at P, (b) no offset at P.

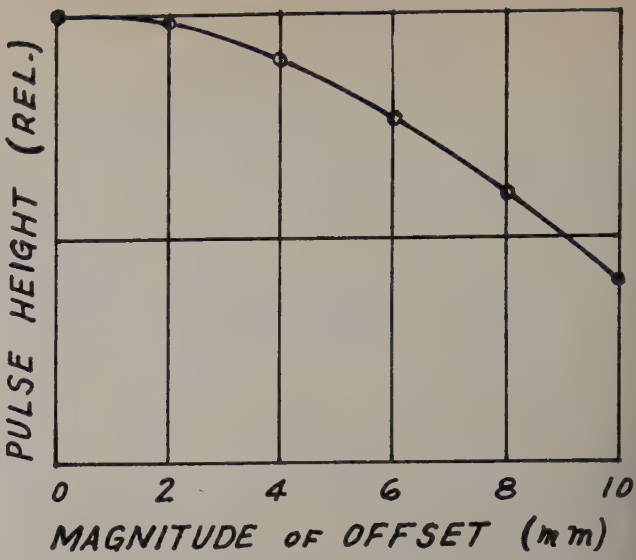

Figure 19 — Pulse height vs magnitude of offset.

You will see that as the frequency f_0 approaches the cutoff frequency of the guide, the basewidth of the pulse extends. The fault location of a waveguide is possible within 40 cm error with this apparatus.

(C) *Fault Location of a Waveguide with a Periodic Time Sweeps Cathode-ray Tube*

Fault location of a waveguide is also possible by using a spark wave and a periodic time sweep cathode-ray tube. Figure 22 shows an oscillogram of the transmitted and the reflected pulses recorded on a periodic time sweep cathode-ray tube whose sweep cycle is 60 cycles and is synchronized with that of the supplying voltage to the spark gap.

The humps in the oscillogram are produced by the timely coincidence between the reflected pulses and the next transmitted pulses. Let

2θ = distance between two adjacent peaks in the oscillogram expressed by electrical angle of 60 cycles

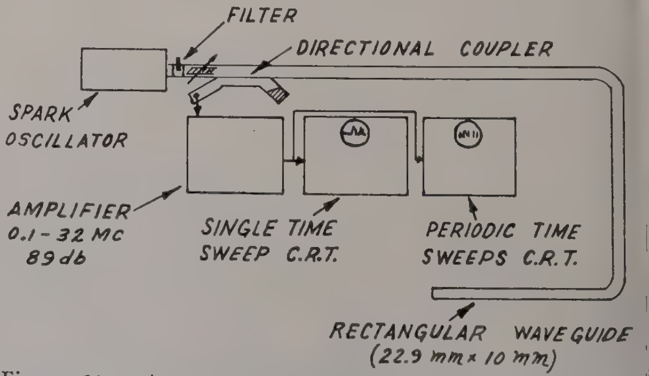

Figure 20 — Arrangement for rectangular waveguide pulse test with spark waves at 9 kMc range.

TABLE II: Measured Value of Distance by Spark Waves and 60 Cycle Periodic Time Sweeps Cathode-Ray Tube (Geometrical Length of l_1 = 20 meters)

	λ=3.2(cm) (v_{g1}=2.16 x 10^8m/sec)			λ=3.4(cm) (v_{g1}=2.01 x 10^8)	
θ (degrees)	20.1	18.2	48.1	33.8	53.3
V_i (volts)	5920	5980	5550	5240	4970
f_r (mc)	5.37	5.4	5.0	4.68	4.4
l_1 (meters)	20	20	21.6	21.4	22.8

λ=free space wavelength in cm.

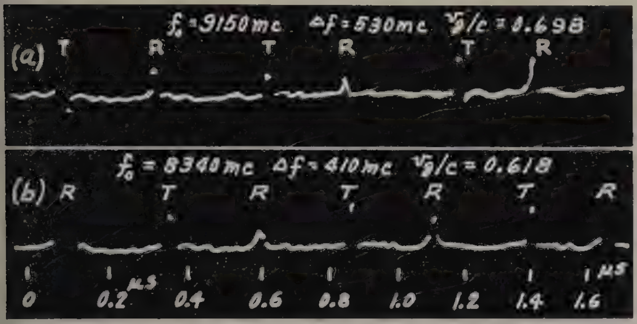

Figure 21 — Oscilloscope traces of transmitted and reflected pulses. (a) f_0 = 9150 Mc, Δf = 530 Mc, v_g/C = 0.698, (b) f_0 = 8340 Mc, Δf = 410 Mc, v_g/C = 0.618.

V_m = crest value of secondary voltage of power supplying transformer to spark gap

$V_i = V_m \cos\theta$

f_{r1} = instantaneous recurrence frequency of spark discharges corresponding to V_i

v_{g1} = group velocity of the wave of frequency f_1.

Then the distance between the fault point and the directional coupler is given by

$$l_1 = \frac{v_{g1}}{2f_{r1}} \qquad (12)$$

The incremental height ($\triangle h$) in Figure 22 represents the amount of the fault.

The measured values of l_1 are tabulated in Table II, which shows that a smaller value of θ gives a more precise result. The measured distance can be changed by the magnitude of the series resistances and the 60 cycle source voltage.

VI. Conclusion

It has been found that a spark dipole immersed in kerosene radiates damped microwave packets at the recurrence frequency of several megacycles determined by the instantaneous value of power supply voltage.

The theory that the higher as well as the fundamental mode resonant frequencies of a waveguide filter can be found by the method of Fourier transform of the standing-wave pattern, has been confirmed by the experiment.

The VSWR of a waveguide element measured by a spark wave is in close agreement with that measured by a continuous wave, and the method of two receiver coherent detection is recommended in the case of spark waves.

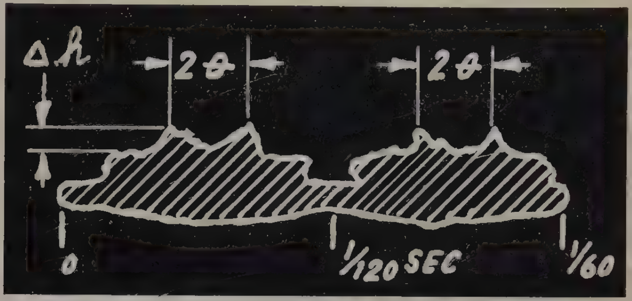

Figure 22 — Oscillogram of transmitted and reflected pulses recorded on a periodic time sweeps cathode-ray tube.

Waveguide pulse tests using spark waves can be performed down to the wavelength range of 1 cm and it has the advantage that the transmitter is quite simple.

VII. Acknowledgment

The author wishes to express his gratitude to Professor Kiyoshi Morita and Professor Kiyoshi Awaya of Tokyo Institute of Technology and to Professor Yoshikazu Kawakita and Professor Kansaburo Kaziwara of Hiroshima University for their invaluable advice and encouragement. He is also indebted to Mr. Hiroshi Ootagaki for his assistance in carrying out the experiments.

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COMPENSATED ELECTROMAGNETIC HORNS†

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I. INTRODUCTION

The E- and H-plane radiation pattern beamwidths of the typical "aperture-type" antenna usually are unequal. Thus, the space radiation polar diagram generally is elliptical in cross section. In some applications, it is highly desirable to use an antenna whose polar diagram is circularly symmetric about its central axis. For the special case of linear polarization, it is evident that a necessary condition for a circularly symmetric polar diagram is attaining identical radiation patterns in the E- and H-planes. Thus, for the general case of elliptical polarization, this condition must be satisfied for both of the orthogonal, linearly polarized vector components of the polar diagram.

By using the aperture modification to be described, the desirable equalization of each pair of E- and H-plane patterns is accomplished almost precisely for one of the most important and useful aperture-type antennas, namely, electromagnetic horns. It should be appreciated that any attainment of these desirable results for horns is tantamount to an attainment of the same results for many cases of another of the most important and useful aperture-type antennas: parabolic reflectors. This statement can be made because horns are very often employed as feeds for parabolic reflectors, and the pencil beam collimated by a parabolic reflector will be circularly symmetric when its feed antenna polar diagram is circularly symmetric.

II. APERTURE COMPENSATION FOR CONICAL HORNS AND SQUARE-PYRAMIDAL HORNS

In this section, after presenting pertinent preliminary considerations, the aperture modification in question is described and its effects on radiation patterns and input VSWR are illustrated and discussed.

A. Preliminary Considerations

The radiation polar diagrams of typical conical and square-pyramidal horns have E-plane patterns which generally are appreciably narrower than their respective H-plane patterns. Two factors responsible for this condition are illustrated pictorially in Figure 1. These factors are:

(1) Because of dominant mode excitation provided by the waveguide transmission line, the E-plane aper-

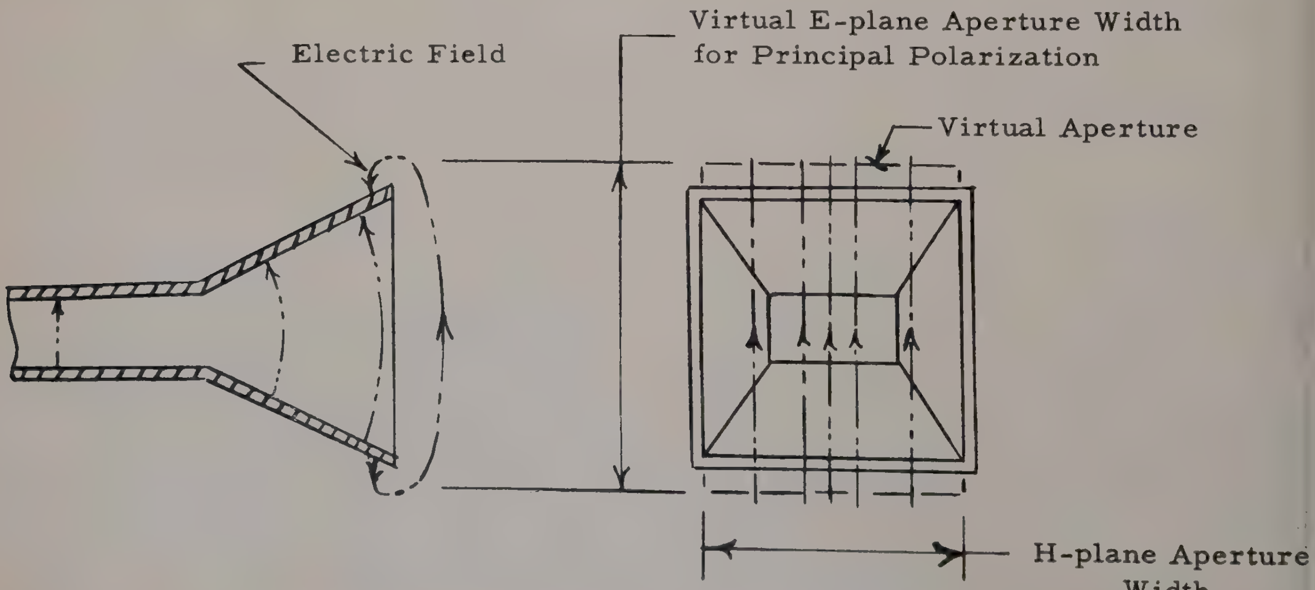

Figure 1 — Virtual aperture of square-pyramidal horn antenna.

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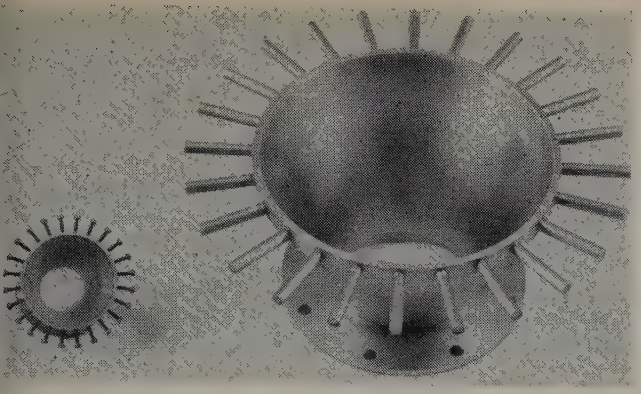


Figure 2 — Compensated horn antennas.

ture illumination function is approximately constant, while in the H-plane the illumination is tapered approximately sinusoidally;

and

(2) In the E-plane, because of fringing electric fields exterior to the horn aperture, the effective or virtual E-plane aperture width is larger than the physical width. In contrast, the electric field in the H-plane is necessarily zero on the walls of the horn, so that the effective H-plane aperture width is the same as the physical width.

These factors are additive, each contributing to relatively narrow E-plane patterns. Although a square horn is used in the illustration, the same two statements apply to conical horns.

Any successful horn modification evidently should counteract either or both of the factors in (1) and (2). In this regard, no modification effective for both broadband operation and *all* polarizations is believed to be possible as far as counteracting the factor in (1) is concerned. Of course, for a very restricted mode of operation, the polar diagram of a pyramidal horn can be made almost circularly symmetric by using a rectangular aperture: the aperture width in the H-plane is increased until the H-plane pattern has the same full-beamwidth as that of the E-plane pattern. But it is clear that this procedure will work only for vertically polarized excitation, where the "vertical" direction is to be understood as the direction parallel to either narrow edge of the rectangular aperture. Thus, for the important cases of all elliptical and circular polarizations only the vertical component of the radiation polar diagram of a rectangular horn can be circularly symmetric. In fact, the long edge of the rectangular aperture is the E-plane aperture width for "horizontal" linear polarization, so that the polar diagram cross section for this component would necessarily be very much more elliptical than that of square-pyramidal horns and conical horns.

Over a broad frequency band, the horn aperture compensation technique to be described produces a nearly circularly symmetric beam for any arbitrary linear, circular, and elliptical polarization so that the resulting "compensated horn" overcomes the specific severe limitation of rectangular horns described in the foregoing paragraph, and also substantially decreases the limitations imposed by the intrinsic factors (1) and (2) presented for conventional conical and square-pyramidal horns at the beginning of this section.

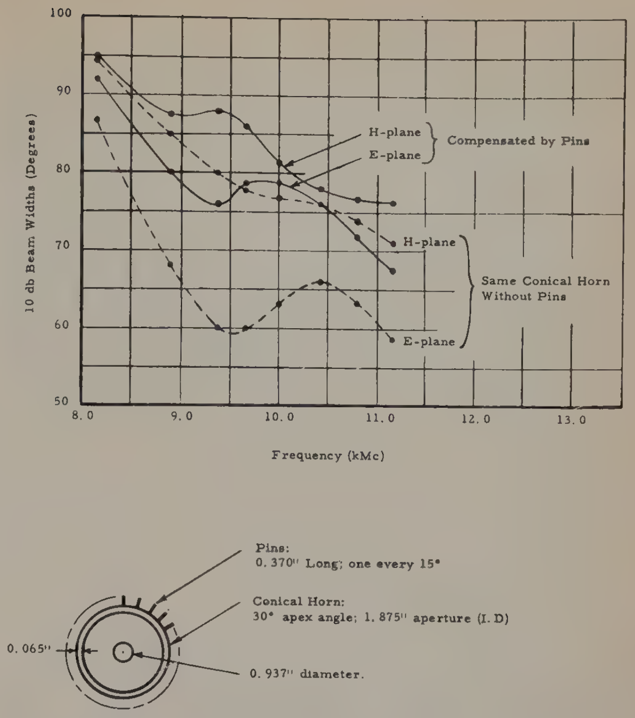


Figure 3 — E- and H- plane beam widths of compensated and standard conical horn -A.

B. Horn Aperture Modification and its Effect on E- and H-plane Ten db Beamwidths

Several aperture modifications of conical horns were investigated in conjunction with a broadband automatic tracking antenna project. The modification found to be the most successful for broadband operation is illustrated by the two modified horns shown in Figure 2. The modification is accomplished by simply fastening small diameter metallic pins or else machine screws on the exterior periphery of the horn aperture. Measured E- and H-plane 10 db beamwidths of two such horns are plotted in Figures 3 and 4 along with corresponding beamwidths of the same two horns measured before their apertures were modified. It is evident that the addition of the pins on the horn perimeter generally causes both the E- and H-plane patterns to become broader, but this effect is always much more pronounced in the E-plane. Radiation pattern 10 db beamwidths in the two mutually perpendicular planes are much closer to being similar for either compensated horn so that, as desired, the compensated polar diagram is appreciably more nearly circular in cross section. The results in Figures 3 and 4 are plotted for a 1.37:1 frequency band; the aperture modification yields similar pattern compensation over broader bands.

A qualitative explanation for this polar diagram compensation is simple to formulate. As illustrated in the bottom drawing in Figure 5, the metallic pins in and near the E-plane effectively diminish the tangential or principally polarized component of the fringing electric fields that exist (top drawing) in and near the E-plane of a simple horn. Thus, the pins cause the virtual or effective E-plane aperture to become smaller, so that the corresponding radiation pattern is broadened. On the other hand, the pins situated in and near the H-plane are adjacent to regions of relatively low incident field intensity, and these pins are also either perpendicular or nearly perpendicular to any existing fringing fields. For these

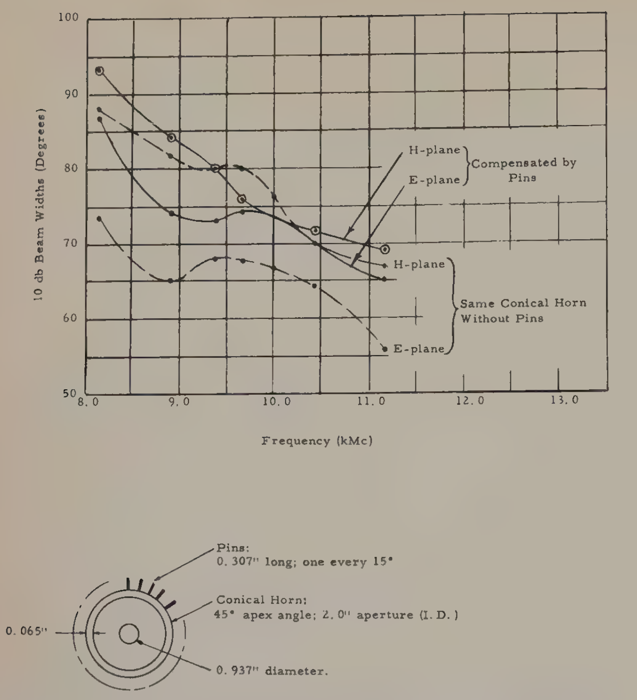


Figure 4 — E- and H- plane beam widths of compensated and standard conical horn -B.

reasons, the H-plane pattern should be changed only slightly. Since the E-plane pattern originally is appreciably narrower than the H-plane pattern, it follows that the addition of the pins should cause the two patterns to approach similarity. In summary, the factor presented in statement (2) at the beginning of Section II-A should be effectively counteracted by this horn-aperture modification.

C. Typical Radiation Patterns and Effect of the Aperture Modification on Input VSWR

Measured radiation patterns of corresponding conventional and compensated conical horns are plotted in Figures 6, 7, and 8. The results in the first two figures are for the horns A and B identified in Figures 3 and 4. A casual inspection of any set of E- and H-plane radiation patterns of corresponding conventional and compensated horns reveals a much higher degree of pattern similarity for the compensated version. Figure 8a shows typical results for a horn having the same flare angle as horn-A and a larger diameter, while Figure 8b is for a horn with a smaller flare angle but nearly the same diameter. These results together with those in Figures 6 and 7 indicate

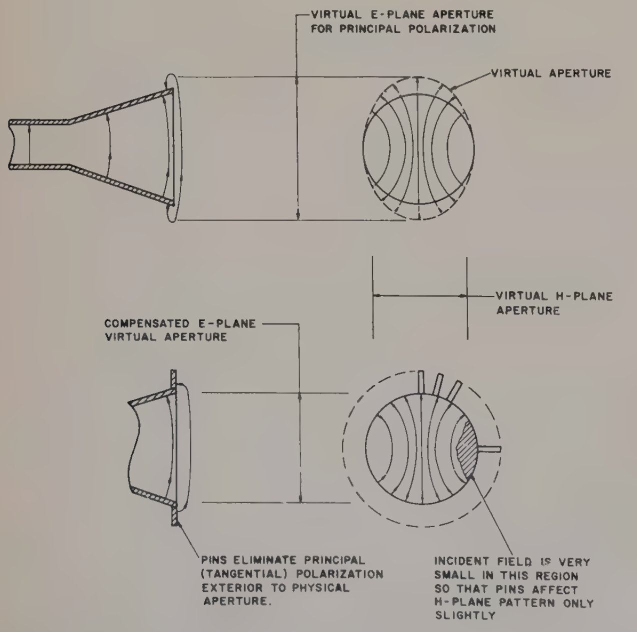

VIRTUAL E-PLANE APERTURE FOR PRINCIPAL POLARIZATION
VIRTUAL APERTURE
VIRTUAL H-PLANE APERTURE
COMPENSATED E-PLANE VIRTUAL APERTURE
PINS ELIMINATE PRINCIPAL (TANGENTIAL) POLARIZATION EXTERIOR TO PHYSICAL APERTURE.
INCIDENT FIELD IS VERY SMALL IN THIS REGION SO THAT PINS AFFECT H-PLANE PATTERN ONLY SLIGHTLY

Figure 5 — Compensation of radiation polar diagram of a conical horn.

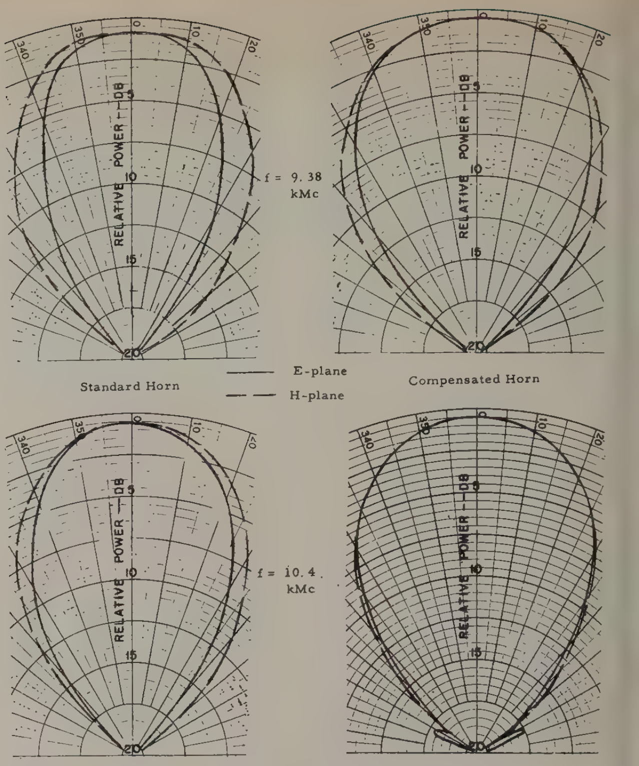


Figure 6 — E- and H- plane patterns of conical horn -A.

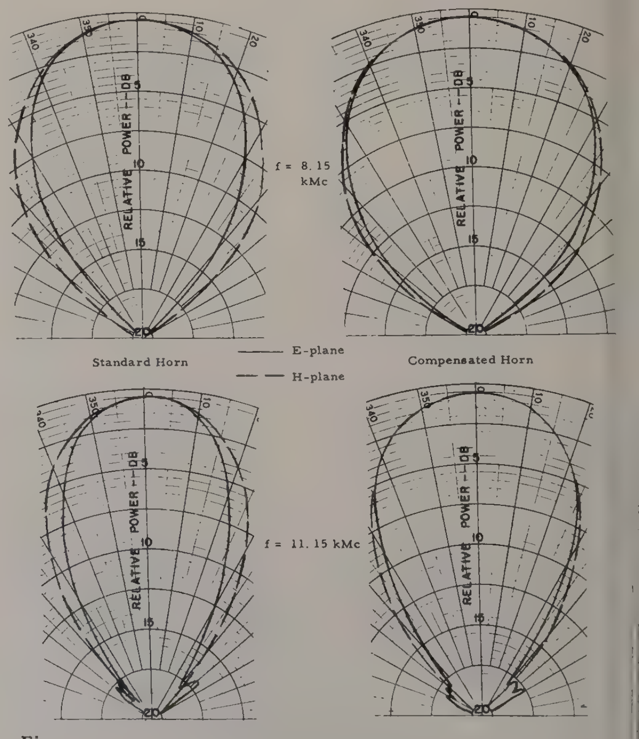


Figure 7 — E- and H- plane patterns of conical horn -B.

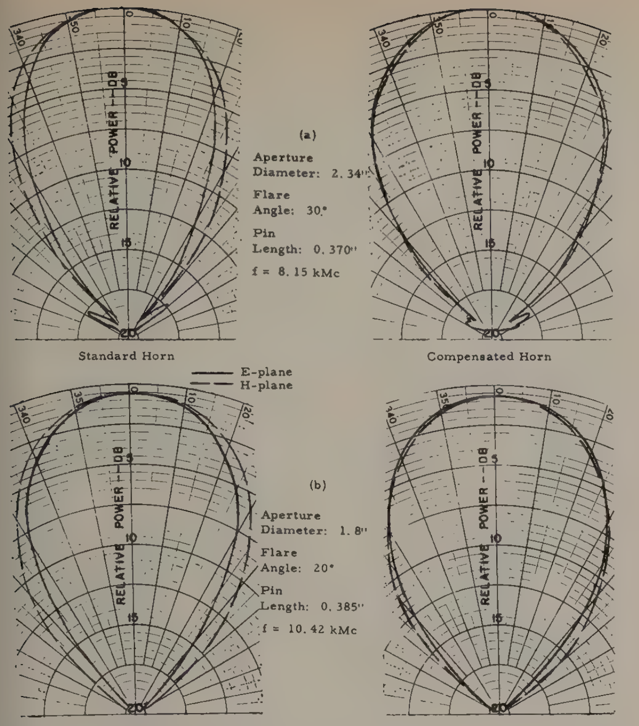


Figure 8 — E- and H- plane patterns of standard and compensated conical horns.

that the aperture compensation technique is effective for a wide range of horn parameters. This effectiveness was indeed observed from pattern measurements for a 1.4:1 bandwidth using conical horns of diameter sizes and flare angles suitable for feeding high gain, parabolic reflectors (reflector gain > 25 db).

Figure 9 illustrates the E-plane radiation pattern variation as a function of pin length for a constant signal frequency. Recall that this pattern is the one that is strongly affected by the pins. In measurements over broad frequency bands, it was found that pin length is not a critical parameter after a certain minimum length is reached. For the bandwidth frequency ratio of 1.4:1, an optimum interval of values for this length was often apparent, the interval depending on the horn flare angle and diameter, but selecting a precise pin length was never an important criterion for desirable broadband performance.

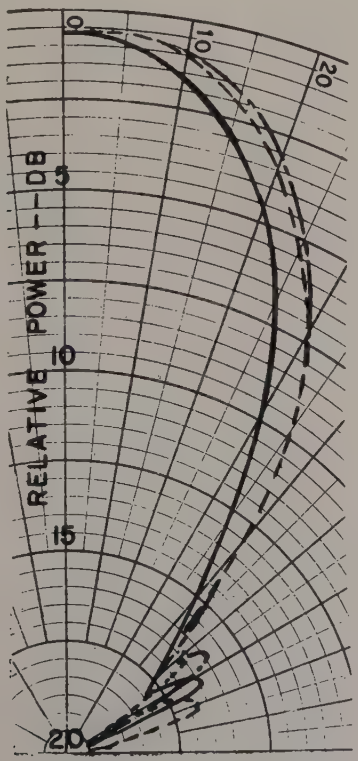


Figure 9 — E-plane radiation pattern versus pin length. (Conical horn -B, f = 10.4 kMc)

Pin Length:
———————— 0.0
- - - - - - - - - - 0.313"
- —— - —— 0.435" and 0.470"

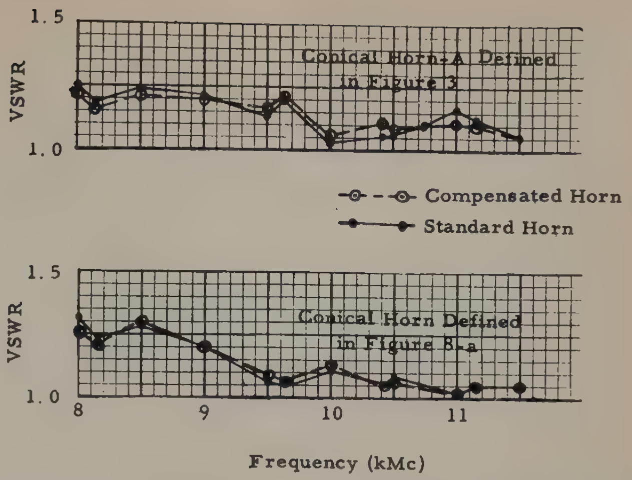


Figure 10 — Input VSWR of compensated and standard conical horns. (Including effect of input rectangular-to-circular waveguide tapered transition.)

The same general behavior was observed as a function of the pin spacing, or the number of pins placed on the horn perimeter. Pin-to-pin spacing was not critical for angular spacings smaller than about 18 degrees. But use of too many pins, more than one about every 8 degrees, did not produce the desired results for a broad band. In particular, placing a continuous metallic rim on the horn — which corresponds to using a zero pin spacing — was found to be quite unfavorable for the polar diagram compensation of interest.

The effect of the aperture modification on the input VSWR of two of the conical horns investigated is shown by Figure 10. It is apparent that the average VSWR of either horn is not unfavorably affected. This result was observed for all horns tested, a total of five. Negligible effect on input VSWR should be expected because the "compensating pins" are placed in such a location where they can reflect only a very small amount of energy back into the horn.

While no measurements were made using square-aperture pyramidal horns, there can be little doubt that the described aperture modification is also effective for this type of horn for all possible polarizations. As already implied, the type of polar diagram improvement considered — equalization of E- and H-plane radiation patterns — is next to impossible to achieve for all polarizations in rectangular horns.

D. Construction Techniques for the Modified Horns

It is believed that two relatively simple methods of fastening the "compensating pins" to a horn should be indicated. In the case of brass horns, an economical technique is the following: tapped holes are made in the wall of the horn near its perimeter (small horn, Figure 2), and ordinary machine screws are soft-soldered in these tapped holes. The heads of the screws do not have

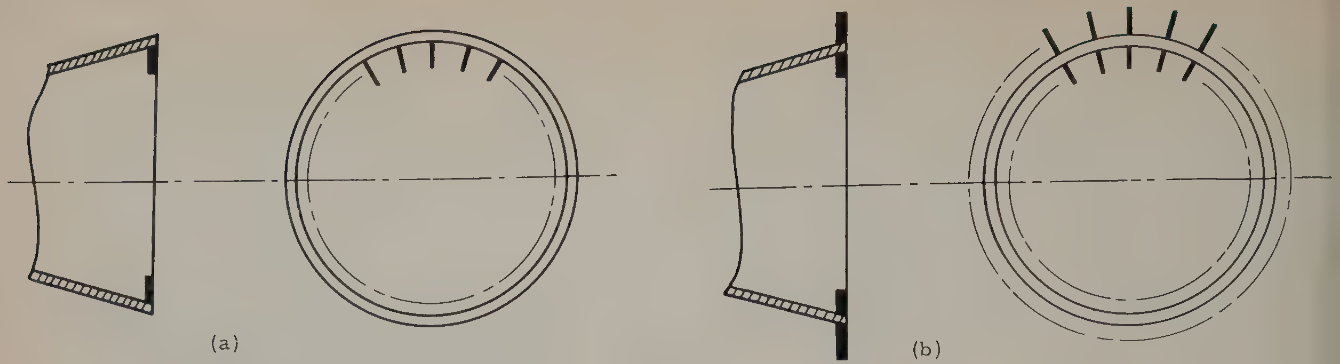


Figure 11 — Other horn aperture compensation techniques.

to be cut away. Press-fitting aluminum rods into holes drilled through a narrow rim on the horn perimeter is a relatively simple technique for aluminum horns. The pins on the large horn in Figure 2 are secured in this manner.

III. OTHER APERTURE MODIFICATIONS

Other aperture modifications that were investigated are illustrated in Figure 11. It was found that the modification on the left in Figure 11 is very effective in the desired manner but only for a relatively narrow frequency band. Results at other frequencies indicate that the pins are excited too strongly, appreciable radiation from the pins themselves generally causing the appearance of high side lobes in the E-plane. The horn aperture on the right in Figure 11 is modified by a combination of the other techniques. In general, no important advantage was obtained from this combination. For bandwidth frequency ratios larger than about 1.1:1, the originally described aperture modification always produced the best results by a wide margin.

IV. SPECIAL APPLICATIONS FOR THE COMPENSATED HORNS

The compensated horns can advantageously replace conventional horns in applications in which either circular polarization or else any elliptical polarization of relatively constant axial ratio is desired throughout as large a solid angle (within the radiation polar diagram) as possible. These applications include not only systems in which horn antennas are used by themselves, but also narrow pencil beam antenna systems employing parabolic reflectors. In the latter cases, the compensated horns would of course be used as the feed antennas.

To understand why the compensated horns will be better than conventional horns for these applications it is necessary to appreciate the general facts illustrated in Figure 12. These facts are:

(1) For any circularly and elliptically polarized antenna, two distinct polar diagrams may be considered to exist, one for each of two orthogonal electric fields E_1 and E_2 in the antenna aperture. Both of these linearly polarized polar diagrams have an E-plane and an H-plane;

(2) One of the two E-planes is the *same* plane P_1 in space as one of the H-planes. The same fact is true for the remaining E- and H-planes, except that these radiation pattern planes are in the space plane P_2 perpendicular to space plane P_1; and

(3) The two orthogonal, linearly polarized electric field components E_a and E_b in the plane P_1 are due to one E-plane pattern and one H-plane pattern, respectively. Similarly, the orthogonal electric field components E_c and E_d in plane P_2 are due to the remaining E- and H-plane patterns.

To illustrate the contention under consideration, let us suppose that circular polarization is desired and assume that an ideal quarter-wave plate is used in circular or square waveguide feeding any horn. An ideal quarter-wave plate will produce circular polarization in the direction of the polar diagram axis. At any angle off-axis in either plane P_1 or P_2 the smallest possible axial ratio is then equal to the difference between the E- and H-plane radiation patterns existing in those planes. This fact becomes evident after considering statement (3), above, and the orthogonally polarized radiation patterns illustrated in Figure 12. Unfortunately, measured axial ratios off-axis are seldom equal to the respective smallest possible values, the reason being that a single effective center-of-phase for both linearly polarized components of radiation for every spatial direction does not exist in any horn. But, if the defined ideal quarter-wave plate is always used, it may be concluded that smaller axial ratios should be distributed over a larger solid angle if a compensated

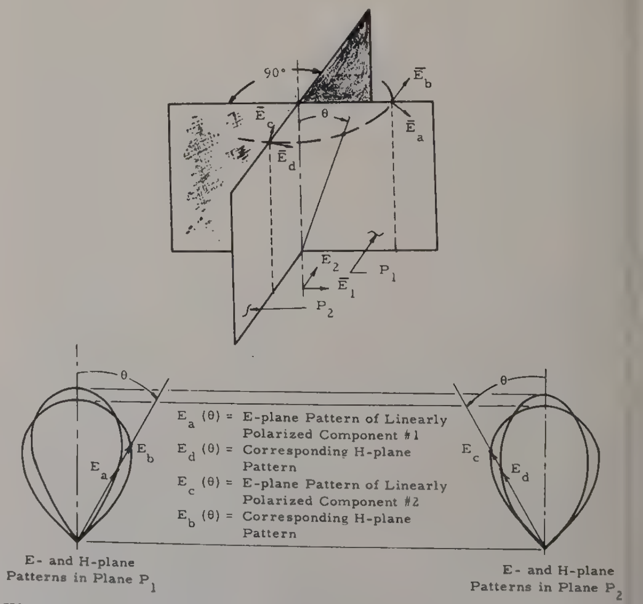
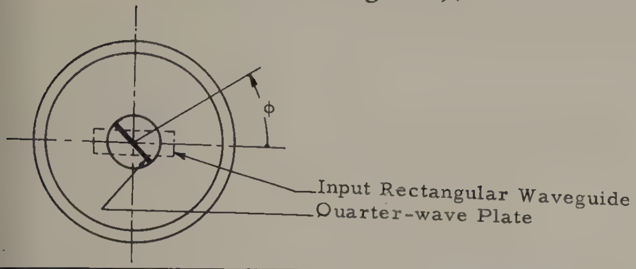

90°
$\bar{E}_b$
$\bar{E}_c$
θ
$\bar{E}_a$
$\bar{E}_d$
E_2
P_1
$\bar{E}_1$
P_2
θ
θ
E_b
E_a
E_a (θ) = E-plane Pattern of Linearly Polarized Component #1
E_d (θ) = Corresponding H-plane Pattern
E_c (θ) = E-plane Pattern of Linearly Polarized Component #2
E_b (θ) = Corresponding H-plane Pattern
E_c
E_d
E- and H-plane Patterns in Plane P_1
E- and H-plane Patterns in Plane P_2

Figure 12 — Multiple E- and H- plane patterns for elliptically polarized antennas.

TABLE I

Measured Axial Ratios on Polar Diagrams of a Compensated and Conventional Conical Horn.

Data for Conical Horn-A
(Defined in Figure 3); f = 10.4 kMc



Angle ϕ (Degrees)	Angle from Horn Axis (Degrees)	Axial Ratio (db)	
		Compensated Horn-A	Conventional Horn-A
Zero and 180	0	0.3	0.3
	10	0.3	0.4
	20	0.8	1.2
	30	1.7	3.7
	35	3.4	5.8
	40	4.8	8.0
	45	7.7	13.4
	50	13.8	>23
45 and 225	20	0.9	1.6
	30	2.3	4.1
	35	2.9	5.1
	40	4.3	7.5
	45	8.0	13.1
	50	13.9	>23
90 and 270	20	1.0	1.8
	30	2.5	4.2
	35	3.1	5.2
	40	4.7	8.7
	45	8.5	14.8
	50	15.8	>23
135 and 315	20	1.0	1.5
	30	2.1	3.6
	35	3.1	5.5
	40	5.3	8.7
	45	7.9	14.7
	50	15.3	>23

horn is used in place of its conventional version. A good example is illustrated by the measured data presented in Table I. Corresponding axial ratios are significantly better (smaller) for the compensated horn. To conclude the present discussion, it is recalled that a quarter-wave plate in circular or square waveguide feeding a square or conical horn may be oriented to produce any desired or selected axial ratio on the polar diagram axis. For all cases, it can be argued that axial ratios off-axis should be appreciably closer to the selected value on-axis after the horn in use is compensated.

It is apparent that the compensated horns can be used to advantage in any system in which a nearly circularly symmetric radiation polar diagram is desired or required for all possible polarizations. The polarization characteristics in the most important applications of this type usually must be changed simply and very rapidly, specifically excluding mechanical re-orientation of either the horn or its transmission line. This tactically important requirement precludes the use of rectangular horns, even for the most simple case wherein only the orientation of linear polarization is varied. For this case employing the compensated horns, because they are fed using circular waveguide, only an input adaptor is rotated. In the most general system, in which arbitrary changes in elliptical polarization are made, a quarter wave plate in the circular waveguide is the only additional part re-oriented.

Using the compensated horns as feed antennas in passive automatic tracking antennas is perhaps the most important example of the special applications described in the preceding paragraph. In this regard, it may be intuitively obvious and it can be proved[1] that a circularly symmetric pencil beam is the optimum type for conically scanning, automatic tracking antennas. Every error-signal characteristic is optimum only for this type of scanning pencil beam; for example, the harmonic content in the error signal is minimized.[2,3] Other specific important characteristics in this class are described in the reference no. 3.

The compensated horns could also be used to improve the error-signal characteristics of certain monopulse tracking antenna systems because a circularly symmetric polar diagram is also the most favorable type for each of the four similar antenna beams generally used in these systems. However, the larger physical area required by the compensated horn-aperture represents a distinct disadvantage for the case of high gain monopulse systems wherein the horns are used as feeds for a single reflector. Thus, any significant advantage not offset by a significant disadvantage obtained by using the compensated horns in monopulse systems would probably be restricted to relatively low antenna gain applications in which the four horns are used without a parabolic reflector.

V. CONCLUSIONS

The radiation polar diagram of conical and square-pyramidal horns is substantially improved by the relatively simple aperture modification described. E- and H-plane radiation patterns are made nearly similar for a broad frequency band. Input VSWR is not affected unfavorably by the aperture modification. The most important advantage of these compensated horns over rectangular horns lies in the fact that the equalization of the E- and H-plane patterns is present for all polarizations in the compensated horns, while this pattern equalization is obtainable only for a single linear polarization in rectangular horns. For this basic reason and other reasons, the compensated horns can advantageously be used in place of conventional horns in several antenna systems.

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A NOMOGRAPH

FOR DETERMINING ELECTRON GUN CHARACTERISTICS

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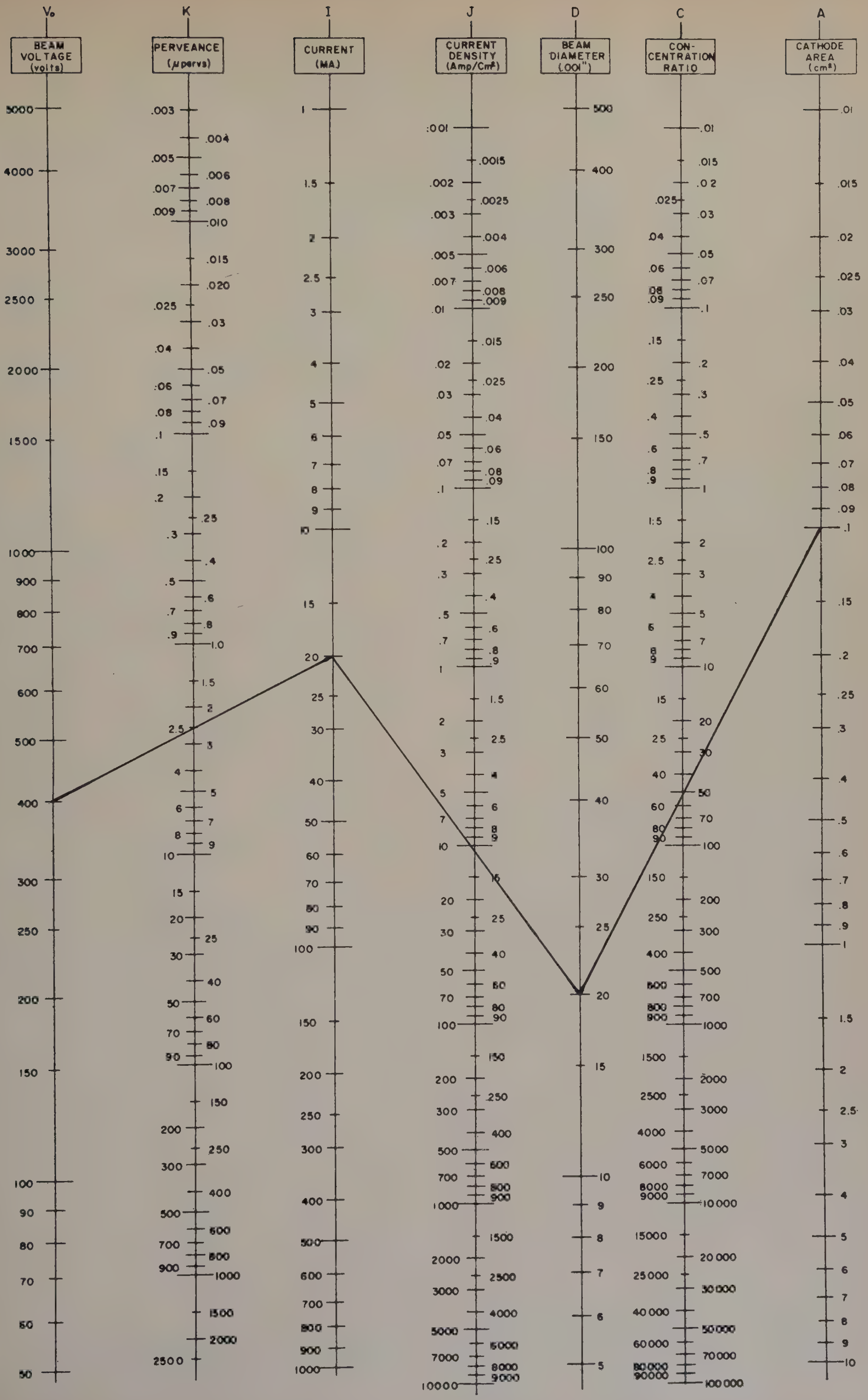
In the design of microwave tubes, a basic problem is electron gun design. The multiple nomograph described here is not a design chart, but it does enable one to obtain the characteristics of a given gun geometry in a minimum of time.

The nomograph is actually three nomographs: one relating voltage and current to perveance through the relation $I = KV^{3/2}$; a second relating beam current and beam diameter to current density in the beam; and a third relating beam diameter and cathode area to concentration ratio. The second and third are useful from the standpoint that beam diameters are usually given in inch units while cathode area and beam current density are normally quoted in metric units.

A simple example will serve to illustrate the use of the multiple nomograph. An electron gun with a cathode area of 0.1 cm^2 and an anode aperture of 0.020 inch produces a total cathode current of 20 milliamperes at an anode voltage of 400 volts. These data are shown on the nomograph and the remaining characteristics are $K = 2.5\ \mu$ pervs, $J = 10\ \text{amp/cm}^2$ and $C \approx 50$.


V₀
BEAM VOLTAGE (volts)
K
PERVEANCE (μpervs)
I
CURRENT (MA)
J
CURRENT DENSITY (Amp/Cm²)
D
BEAM DIAMETER (.001")
C
CON-CENTRATION RATIO
A
CATHODE AREA (cm²)

DESIGN CHART FOR QUARTER-WAVE STUBS

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Quarter-wave stubs are commonly used in coaxial and strip transmission lines. Applications include:

(1) Supporting the inner conductor of long sections.
(2) Making right angle corners.
(3) Providing DC return or bias without an RF short.

Such stubs can have very low VSWR over large bandwidths, if designed with a symmetrical transformer as shown in Figure 1 where λ_o is the wavelength at center frequency. The VSWR against frequency curve then appears as shown in Figure 2, where V_m is the maximum VSWR over a bandwidth of $(f_2 - f_1)/f_o$.

The principle of this design was given by Moreno,[1] and Ragan[2], and Young[3] gave design information based on a bandwidth taken between the two outer zeros of reflection. Muehe[4] later gave design formulas defining the bandwidth as in Figure 2; his formulas were used to compute the design chart, Figure 3, which is accurate enough for any practical design to be read off directly. This chart covers all bandwidths in increments of 20%, for Z_2 from 0.1 to 10.0.

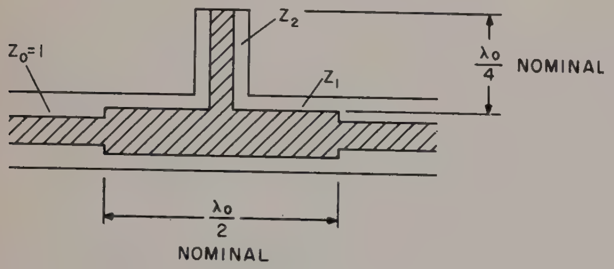

Figure 1 — Quarter-wave stub in coaxial line.

$$f_o = \frac{f_1+f_2}{2}$$

$$\text{BANDWIDTH} = \frac{f_2-f_1}{f_o}$$

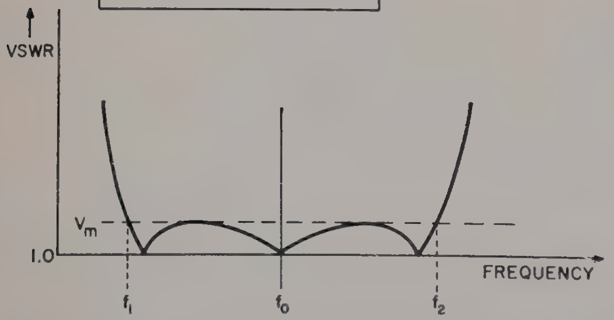

Figure 2 — VSWR vs. frequency response of quarter-wave stub.

For example, if it is required to design a coaxial line stub with VSWR better than 1.05 over an 80% band, then from Figure 3,

$$Z_2 \geq 1.7$$

We may, for example, pick $Z_2=2$. Then from Figure 3, $Z_1 = 0.87$.

Acknowledgment

This work was supported under Contract DA 36-039 SC-74862.

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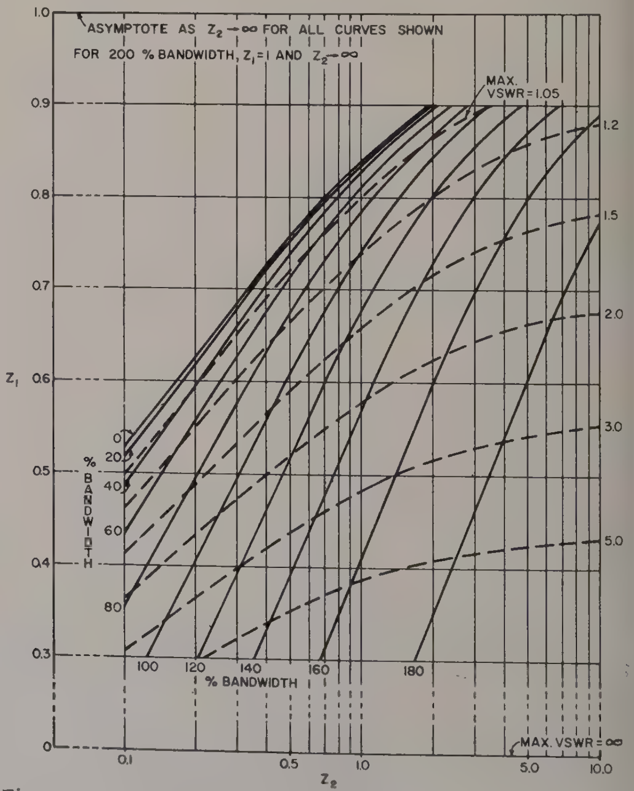

Figure 3 — Design chart connecting Z_1 and Z_2 for all bandwidths, in 20% increments (continuous lines); together with VSWR contours (broken lines).

THERMAL NOISE IN MICROWAVE SYSTEMS

Part III

Practical Problems and Ultimate Limits On Amplifier Noise Figures

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Two different topics are discussed in this final article. The first portion considers some of the practical difficulties which arise when one attempts to achieve or measure an ultra-low-noise receiving system using a maser or other low-noise amplifier. The success which workers in the maser field have had in overcoming these difficulties is indicated by summarizing some of the experimental maser noise figures.

The second portion of the article then considers the fundamental question: is there a theoretical lower limit to amplifier noise figures? It is shown that there is, indeed, a very basic lower limit, set by the uncertainty principle of quantum theory (or by spontaneous emission, or by zero-point energy, depending on the viewpoint taken). The maser is shown to just reach this lower limit. Various other 'noiseless' quantum counters are also discussed, and their relation to the ultimate noise limit pointed out.

A. PRACTICAL PROBLEMS AND EXPERIMENTAL RESULTS

Even when one has a very-low-noise amplification mechanism, such as the maser amplification mechanism, certain practical difficulties still stand in the way of achieving low noise in an overall amplifier. This section will discuss some of these practical difficulties, with particular application to maser amplifiers, and will summarize the experimental noise figures achieved to date in maser amplifiers.

Noise Effects of Small Losses Before the Amplifier

Probably the major difficulty in achieving a very-low-noise amplifier system is the fact that even small losses in a system ahead of the amplifier input can contribute relatively large amounts of noise. In maser amplifiers, the small losses in circulators and in the input line leading down to the maser itself are especially troublesome. We have already analysed the noise effects of transmission line loss in Part I. Those results were derived for a lossy transmission line, but the results apply generally to any sort of insertion loss*. According to Part I, the principle effect of a small insertion loss at temperature T is to add into a system a noise contribution given by

$$\text{Added noise} = \frac{\text{Loss in db}}{4.34}\,\text{kTB}, \quad \text{Loss} < 1/2\ \text{db} \qquad (1)$$

If T is room temperature, 290°K, this says that each tenth of a db of insertion loss adds approximately 7°K of thermal noise into a system. If the loss is on the input side of an amplifier, this additional noise adds directly to the noise input of the amplifier, and so in effect adds directly to the amplifier's noise temperature. Note that even a tenth of a db of loss at room temperature contributes 7°K, or several times more noise than the 2°K or so of internal noise in a maser amplifier spin system at helium temperature.

For losses larger than ~1/2 db, the situation is even worse, since not only is noise added in by the losses, but also the signal is significantly attenuated in passing through the losses. The signal-to-noise ratio is thus doubly degraded. Hopefully, however, any reader engaged in construction of a low-noise system will be able to keep his losses within the approximation above, so that we need not go into the effects of larger losses.

Effects of Second Stage Noise

A maser or other low-noise amplifier is generally followed by a second-stage amplifier with a much higher noise figure. The overall noise temperature of the amplifier then depends on the gain of the first stage, which should be high for best results. To analyse this problem, consider an overall system consisting of two stages with gains and noise temperatures G and G′, and T_a and T_a', respectively. If the source temperature is T_g, then the total noise power out of the overall system is

$$\text{Noise output} = G'G\,k(T_g + T_a)B + G'kT_a'B \qquad (2)$$

The T_g term is, of course, just the amplified source noise. Dividing the second and third terms by the overall gain GG′ times kB gives the overall noise temperature of the two stages as

$$T_{a(\text{overall})} = T_a + T_a'/G \qquad (3)$$

This is a well-known result. If the second-stage contribution T_a'/G is to be small compared to the first stage, the gain G of the first stage must be $> T_a'/T_a$. If the first stage, for example, has $T_a = 10°K$, and the second stage has $T_a' = 1000°K$ (a 6-1/2 db noise figure), then the first stage gain must be greater than 100, or 20 db, to override the second-stage noise.

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* *The results of Part I could have been derived from a general model with the aid of the noise theorem, rather than using a specific transmission-line model.*

The second stage can affect noise performance in another way if the first-stage amplifier is a type which is sensitive to noise power coming back into its output. Although the second stage may present a matched load to the first stage, the effective temperature of this load may be substantially higher than room temperature, due to noise generation effects in the second stage. For example, the effective noise temperature of the noise coming *out* of the input port of a traveling-wave-tube amplifier used as a second stage has been measured to be about twice room temperature. The effective noise temperature coming back from the input of a 416B microwave triode has been quoted as 400°K at 450 Mc/s. Crystal mixers can send substantial amounts of noise back out of their inputs, with effective temperatures of 2000°K or greater.

Measurement Techniques for Low-Noise Amplifiers

Before discussing experimental results obtained from practical masers, it will be useful to consider how the noise temperature of a very-low-noise amplifier can be measured. A standard measurement technique is to follow the amplifier with a receiver having a precision attenuator in either the r-f or i-f section, plus an output meter. Two well-matched sources at temperatures T_{g1} and T_{g2} are alternately connected to the amplifier input. The measured quantity is then the additional attenuation which must be introduced with the precision attenuator when the hotter source is connected, in order to obtain the same meter reading as when the colder source is connected. See Figure 1 for a typical example of such a measuring system.

If T_a is the total internal noise temperature of the amplifier being measured and G is its gain, and if T_a' and G' are the same quantities for the receiver or second stage, then the noise powers to the output meter with each of the two sources connected, leaving out the attenuator, will be

$$\begin{aligned} P_{n1} &= G'Gk(T_{g1}+T_a)B + G'kT_a'B \\ P_{n2} &= G'Gk(T_{g2}+T_a)B + G'kT_a'B \end{aligned} \qquad (4)$$

The amount of attenuation which must be added for the hotter source T_{g2} to make $P_{n2} = P_{n1}$ is just the ratio $r = P_{n2}/P_{n1}$. Using this quantity, one can manipulate Equations 4 to obtain the expression

$$T_a = \frac{T_{g2} - r\,T_{g1}}{r-1} - \frac{T_a}{G'} \qquad (5)$$

This gives the amplifier noise temperatures T_a in terms of the measurable quantities T_{g1}, T_{g2}, r, T_a' and G.

A measurement of this type requires considerable precision. To obtain some idea of the precision required, one can take the differential of Equation 5 with respect to each of the quantities involved. The most critical quantity is usually the added attenuation r, which contributes an error in the final result given by

$$\delta T_a = \frac{T_{g2} - T_{g1}}{(r-1)^2}\,\delta r \qquad (6)$$

where δT_a is the error in T_a caused by an error δr in r. The temperatures T_{g1} and T_{g2} are often liquid nitrogen (77°K) and room temperature. (Lower temperatures would be better, but a matched termination at liquid helium may be difficult to construct and inconvenient to use). The ratio r is then about $r = 3.4 = 5.3$ db. Putting these numbers into Equation 6, and converting r to decibels by the relation $r_{db} = 10 \log_{10} r$, yields

$$\delta T_a \approx 30\,\delta r_{db} \qquad (7)$$

Therefore, to measure T_a to within 1°K requires that r be measured to within 0.03 db. Furthermore, the gain of the system must remain constant to within this amount during the measurement, including during the exchange of sources. Fortunately, it is only gain *stability* of this order that is required; the absolute value of the gain does not need to be known to this accuracy.

Noise Sources in a Circulator Cavity Maser: Theory and Experiment

As was noted in Part II, there have been only a few noise measurements on solid-state masers, but these have all been in good agreement with theory. The original solid-state maser noise measurement, made in 1957 at Lincoln Laboratories on a 2800 Mc/s cavity maser[10, 11], remains the classic measurement of noise in a cavity maser. In the following, we will list the significant or possibly significant noise sources in a circulator maser, and illustrate each noise source with data from the Lincoln experiment.

Figure 1 is a diagram of the circulator maser and noise measurement setup used by Lincoln. In addition to the inherent spontaneous emission noise in the maser cavity, there will be additional noise introduced into the overall amplifier by losses in various parts of the system, by the effects of impedance mismatches and non-ideal circulators, and by other effects. In fact, the additional noise considerably exceeds the spontaneous emission noise in all practical masers to date.

Any attempt to analyse the additional noise sources in a system such as Figure 1 exactly and in detail leads to rather complicated equations. However, in practical situations all of the various noise effects are usually small enough so that they can be analysed separately, one by one, and their noise contributions then added to obtain the total noise. We will follow such a simplified approach, remembering that it is an approximation. The list of possible noise sources in a circulator maser such as Figure 1 includes:

a) The forward insertion loss from port 1 to port 2 of the circulator. This loss will contribute noise in accordance with the discussion of Equation 1. In the Lincoln case, this loss (which is difficult to measure accurately) was between 0.1 and 0.3 db, or between 7°K and 21°K of additional noise for a room-temperature circulator. These attenuation values seem to be typical for carefully constructed ferrite circulators. Hughes Research Laboratories has taken advantage of the much smaller size of a circulator at 10,000 Mc/s to insert the circulator directly in the liquid helium dewar, thus essentially eliminating this troublesome noise source.

b) The insertion loss of the cable or other line going from the circulator down to the maser cavity. To give some typical numbers, a one-yard length of solid coaxial line with Teflon dielectric and silver-plated stainless-steel conductors may have an insertion loss of 1/2 db at 3000 Mc/s. In the Lincoln case, the 27 inch coaxial line had an attenuation of 0.7 db at room temperature, and 0.4 db in operation with the lower portion at helium

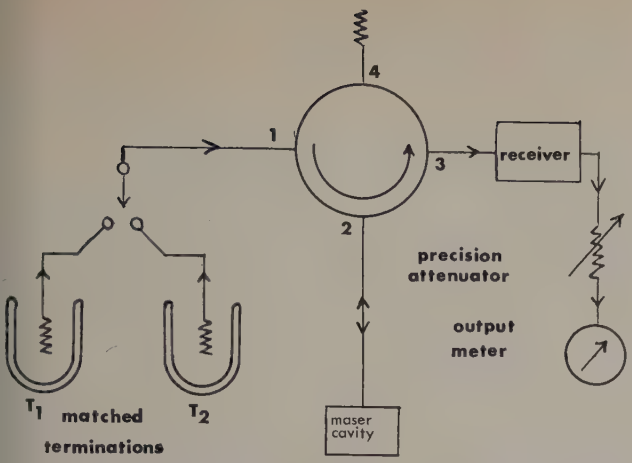

Figure 1 — A circulator maser, and a typical arrangement for measuring noise temperature.

temperature. Since both the temperature and the loss vary along the line under operating conditions, Equation 1 is not directly applicable. The required expression is somewhat more complicated. Let L(x) be the loss in db per unit length as a function of distance x along the coaxial line, and let T(x) be the temperature as a function of distance. Then the added noise term of Equation 1 will be replaced by

$$\text{Added noise} = kB \int_{0}^{l} [L(x)/4.34]\,T(x)\,dx \qquad (8)$$

where l is the length of the coaxial line. In practice, neither L(x) nor T(x) is likely to be known exactly. The Lincoln workers estimated that, in their case, this term amounted to between 7°K and 23°K. This obviously serious noise source could be greatly reduced if a much less lossy waveguide could be used as the input line. Coaxial line is more convenient than waveguide below about 5000 Mc/s, however, because the waveguide becomes rather large and because variable coupling to the cavity is more easily obtained with a coaxial line. Coaxial line losses can be reduced by employing larger diameters, air or polystyrene-foam dielectric, and carefully silvered and polished conductors. Unfortunately, silver-plating the inside of a long stainless-steel tube is a difficult operation.

c) Noise coming into ports 3 and 4 of the circulator from the load or second stage, and being transmitted out port 2 to the maser. This noise source would be nonexistent with an ideal circulator. However, real circulators have finite reverse isolation between ports and so some thermal noise from other ports gets into the maser input line. The Lincoln circulator had reverse isolation between ports 4 and 3, and between ports 4 and 2, of 35 db and 27 db, respectively. Since room temperature of 290°K reduced by 30 db is only 0.29°K, this noise source was negligible. Reverse isolations of this sort can usually be obtained with a good circulator at a spot frequency. However, obtaining this order of reverse isolation over broad bandwidths, while still keeping the forward insertion loss very low, is not always an easy task for the designer of a circulator.

d) Thermal noise coming from the termination on port 4, reflected back into port 1 from the generator or source. If the voltage reflection coefficient looking from the circulator out port 1 into the generator or source is ρ, and if the temperature of the load on port 4 is T_4, then the contribution from this mechanism will be $|\rho|^2 T_4$. As an example, if $T_4 = 290°K$ and $|\rho| = 0.05$ (VSWR = 1.1), this contribution gives only 0.75°K. A VSWR of 1.5, however, would raise this to 12°K. In the Lincoln case, the VSWR of the carefully matched source was 1.04 and this contribution was entirely negligible. The VSWR of, for example, an antenna might not be this good, particularly over a broad bandwidth.

Summing up these noise contributions for the Lincoln maser, and adding the theoretical value of 2°K for the maser cavity and spin system, gives a predicted total internal noise temperature for the complete maser amplifier of between 16°K and 46°K. Careful measurements by the procedure described above gave a measured value of 20°K with an uncertainty of ±5°K. Comparing theory and experiment makes it evident that the noise from the maser cavity and spin system must have been very little if any greater than the theoretical 2°K. Moreover, the noise sources in the circulator and the coaxial line were probably nearer the lower than the upper limits which were estimated.

Noise From the Pump Power

A major virtue of the three-level maser amplification process is that there is no conversion of pump power into noise at the signal frequency, at least according to the simple theory. When one considers the relative magnitudes of the spontaneous emission noise power and the pump power, however, one might worry that some small nonlinearity in the spin system, the maser crystal dielectric, or the cavity metal would be sufficient to swamp the spontaneous emission noise with noise coming from frequency-converted pump power. As an example, in the Lincoln Laboratories cavity maser the signal bandwidth was 60 kc/s. Using this bandwidth for B and a temperature of 2°K for T, one obtains a spontaneous emission noise power kTB of 10^{-18} watts. On the other hand, the pump was ~10^{-2} watts. The conversion loss from pump to signal frequency due to any nonlinearities must, therefore, have been in excess of 160 db to keep converted pump power below the spontaneous-emission noise level. The noise measurement discussed above seems to indicate that this is indeed the case and that noise from the pump power is not a problem. Weber has reached the same conclusion on theoretical grounds [16, 17].

One consequence of this would seem to be that one can, if desired, pump a three-level maser with a noisy pump source, without deterioration of the noise figure. In fact, one can apparently even use a pump source which is so strongly noise modulated as to be essentially white noise. The only requirement is that the integrated power density over the pump-frequency bandwidth be sufficient to keep the pump transition saturated.

Noise Measurements on a Traveling-Wave Maser System

Circulator noise problems are no longer present in a traveling-wave maser, but losses in the input coaxial line remain a major source of difficulty. Noise measurements have been performed, for example, on a Bell Telephone Laboratories traveling-wave maser, which amplifies at 5.65 kMc/s[2, 3]. The 30 inches of carefully silvered input line in the BTL maser had a room-temperature loss of 0.28 db. In operation the actual temperature gradient along the line was monitored, and the noise contribution from the line was calculated to be between 8°K and 9°K. The theoretical contribution from the maser itself was 2.4°K, giving a total theoretical noise temperature between 10.4°K and 11.4°K. This was in excellent agreement with the measured noise temperature of 10.7 ± 2°K. The measurements were made using an arrangement very similar to the Lincoln arrangement shown in Figure 1.†

The BTL maser was also connected to a special folded parabolic horn antenna, and a total input noise temperature of 18-1/2°K, including sky noise, was obtained with the antenna pointing at the zenith[2]. The noise sources in the system were allocated as follows:

Maser proper	2-1/2°K	
Input coaxial line	8°K	
Complete maser amplifier		*10-1/2°K*
Antenna and waveguide losses	3-1/2°K	
Back and side-lobe pickup	2°K	
Maser plus antenna		*16°K*
Sky Noise (zenith)	2-1/2°K	
Total system noise (zenith)		*18-1/2°K*

This is undoubtedly one of the lowest system noises ever achieved, and represents very careful systems engineering. The BTL workers also verified that, as the antenna was rotated down from the zenith, the other noise contributions remained essentially constant while the background sky noise varied according to the theoretical expression

$$T_{sky}(\theta) = \frac{T_{sky}(\theta=0)}{\cos\theta}, \quad \theta < 80^\circ \qquad (9)$$

where θ is the angle between the zenith and the antenna beam. Figure 2 is a plot of the sky noise and the total system noise vs. the angle θ. Note that the total noise temperature of the system has only risen from 19° to 38° even when the antenna beam is only 7 degrees above the horizon.

Recent BTL developments have reportedly led to still further improvements, chiefly through reduction of the input coaxial line losses.

A Direct Measurement of Spin-System Noise

The most accurate measurement yet made of the noise contribution from a helium-temperature maser spin system was also obtained by the BTL group, using a slightly different model of the same traveling-wave maser. In order to make the measurement, the input coaxial line was replaced by 10 feet of flexible coaxial cable, most of which was immersed in the liquid helium bath with the maser. The coaxial cable, which had a special nichrome center conductor, had an insertion loss of 18 db at room temperature and 17 db at helium temperature. Thus, in operation it provided essentially a matched helium temperature source for the traveling-wave maser. By applying a variable calibrated noise source with a high noise temperature to the other end of the cable, and knowing the insertion loss of the cable, additional noise could be sent into the maser, i.e., the source temperature of the maser could be raised above helium temperature by small but yet accurately known amounts. The increase in output noise power from the maser could then be observed. Using this technique, the maser's internal noise temperature was measured to be 2.0 ± 0.5°K, as compared with a theoretical noise temperature for this maser of 2.0 ± 0.1°K*. This is a beautiful and striking confirmation of the low inherent noise of the maser amplification process.

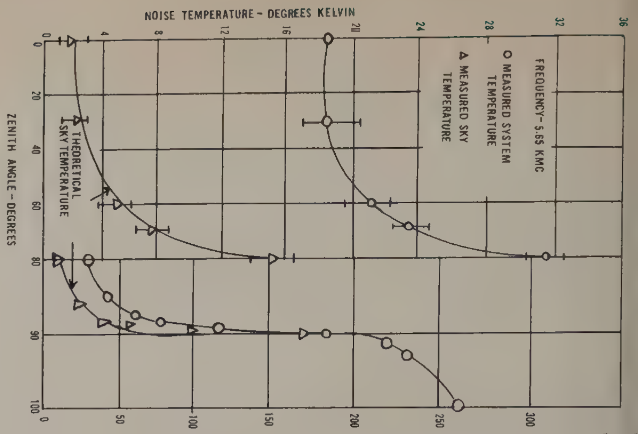

Figure 2 — Measured curves of sky noise temperature and of total system noise temperature (including maser noise, antenna losses, and sky noise) at 6000 Mc/s, plotted vs. angle of antenna beam from the zenith.[3]
(*Courtesy of Bell Telephone Laboratories and J. Appl. Phys.*)

Summary of Other Maser Noise Measurements

Only a limited number of other maser noise measurements have been made. Table I summarizes those which have been reported. Two points may be of special interest. The first is the large difference between the inherent noise temperature of a maser and the practical results for complete systems, which are ten to a hundred times noisier than an ideal maser. The very carefully engineered Bell Labs traveling-wave-maser system is the major exception to this rule. Much work obviously remains to be done. A second point of interest is the excellent agreement between theoretical and experimental noise temperatures of the Hughes nitrogen-temperature maser[9]. At nitrogen temperature, the spontaneous-emission noise contribution from the spin system is of the order of nitrogen temperature. It thus forms a much larger fraction of the total noise, as compared to the ohmic loss contribution, than is the case in helium-temperature masers. Therefore, the good agreement in this case is further strong verification for the maser noise theory.

Gain Stability Considerations

A final point on ultra-low-noise systems and measurements is that in some systems and applications a random fluctuation in receiver gain will deteriorate system performance in essentially the same way as would additional noise in the system. Therefore, considerable attention may have to be paid to eliminating both short-term and long-term gain instabilities. This is often a difficult and aggravating assignment. It may be noted that the maser

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† *In the reverse direction, a traveling-wave maser, because of its reverse isolation, is essentially a lossy transmission line at helium temperature. Therefore, the noise coming out of the input port of a traveling-wave maser has a noise temperature approximately equal to helium temperature. (The noise temperature may be slightly 'warmed up' in passing up through the input cable). Putting a short circuit on the traveling-wave maser's input line reflects this helium temperature noise back into the maser, to serve as the effective input noise. Therefore, a good way to obtain an effectively helium temperature source for checking the noise figure of a traveling-wave maser is to simply short circuit the input line.*

* *The BTL group has recently reported internal noise temperatures as low as 0.5°K.*

TABLE I

NOISE MEASUREMENTS ON SOLID-STATE MASERS

Laboratory	Signal Frequency Mc/s	Bath Temperature	Measured Noise Temperatures
Lincoln Laboratories[8]	450	1.25°K	70°K for complete amplifier[a] 170°K for amplifier + antenna + sky noise
Lincoln Labs.[10, 11]	2800	1.25°K	20 ± 5°K for complete amplifier.
Bell Telephone Labs.[2, 3]	5650[b]	1.6°K	2°K for maser proper 10°K for complete amplifier 16°K for amplifier + antenna
Hughes Aircraft Co.[7, 9]	9000	4.2°K	65°K for complete amplifier, incl. second stage. 173°K for amplifier + TR tube, rotary joint, waveguide switch, waveguide run, and antenna.
Hughes Aircraft Co.[9]	9140	77°K	100°K for maser proper vs. 95°K theoretical value.
Columbia Univ. — Naval Research Lab.[6]	9500	1.4°K	85°K for amplifier + ferrite switch, antenna and sky noise.

[a] Since no circulator was available, a directional coupler was used instead, with substantial degradation of the noise temperature.
[b] A traveling wave maser.

in contrast to certain competitive low-noise amplifiers, is inherently a very stable device. Fluctuations due to pump modulation, either AM or FM, are inherently suppressed by the fact that the pump operates on a relatively wide resonance line, in a saturated condition. The maser is temperature-stabilized by its own helium bath. Moreover, the active maser crystal is an extremely rugged element, since the active spins are locked away safely in the crystal lattice. Even enormous overloads can cause no damage or long-term deterioration of the spin system.

B. ULTIMATE LIMITS ON AMPLIFIER SENSITIVITY

This concluding portion of these articles is concerned with a very fundamental question: supposing that all practical difficulties, such as ohmic losses and so on, can be eliminated, is there then any theoretical *ultimate lower limit* to the noise figure obtainable in an amplifier (microwave or otherwise)? As we will see, it is not easy to answer this question simply. There does seem to be, however, some sort of very fundamental ultimate lower limit on an amplifier's noise performance. This limit is set by the uncertainty principle of quantum mechanics, if you like, or by spontaneous emission, or by zero-point fluctuations, depending on the viewpoint you choose to adopt. As a specific example, it is easily shown that a perfect maser just reaches this ultimate lower limit.

The ultimate lower noise limit of an amplifier, we will see, is directly proportional to the frequency of the amplifier. The ultimate noise figure is quite small at microwave frequencies, corresponding to an amplifier noise temperature of ~1°K. Note that present-day maser amplifiers approach quite close to this ultimate lower limit. At very high frequencies, for example the optical light region, the lowest possible noise figure is proportionately higher, e.g., the minimum noise temperature for a coherent amplifier at optical frequencies is ~25,000°K. Thus, if coherent amplifiers are constructed at optical frequencies, as seems likely, they will be very noisy devices — at least by conventional microwave-frequency standards.

In the following, we will also describe some so-called *quantum counters:* devices which can, in principle, detect incident signals with perfect efficiency and absolutely no noise, at least in one sense of the term. These devices do not, however, get around the ultimate lower noise limit just mentioned. If the general noise limit is interpreted more broadly, it applies to quantum counters too. The important point, we will see, is that quantum counters are not really true amplifiers, in the sense that they do not amplify coherently and do not preserve the phase of the detected signal.

Even though we can find this ultimate lower limit on amplifier noise, a still more fundamental problem has not yet been completely solved. Note that the noise in an amplifier or a communications system is important, not so much in its own right, but rather because it limits the *channel capacity* of the system. Shannon's communication theory[15] gives an expression for the information-transmitting capacity of a channel in the presence of a certain amount of noise. However, Shannon's theory is limited to the classical case — it entirely ignores quantum effects, particularly the fact that electromagnetic signals come in photons or quanta rather than continuous waves. Quantum effects become important at high enough frequencies and low enough signal levels, and Shannon's theory is then no longer sufficient. The question of how quantum effects modify the channel capacity formulas has only been partially solved to date, chiefly in several papers by Stern.[18] One of Stern's more important results will be given below.

We should note in advance that the arguments in the following sections tread on rather shaky ground. We will be attempting to describe in semi-classical terms what are really quantum phenomena. Worse, we will be trying to use a loose mixture of classical and quantum theory by using quantum concepts in an imprecise fashion. To describe properly the behavior of an amplifying system when one gets down to the quantum level, one should if possible use a rigorous quantum approach. This is not easy, however, and the following non-rigorous discussions appear to have at least some usefulness in understanding the ultimate noise behavior of amplifiers and detectors.

The Uncertainty Principle

One piece of information we need in the following is the *uncertainty principle* of quantum theory. Those readers who have had an introduction to this principle will know that it asserts that there is an upper limit to the combined precision with which two conjugate physical quantities can be simultaneously measured. A common example used to illustrate the uncertainty principle is the statement that the instantaneous position and the instantaneous velocity of a moving particle cannot be simultaneously measured with arbitrarily high precision. In fact, if p is the momentum of the particle and x is its position, and if $\triangle p$ and $\triangle x$ are the rms errors in the measurement of these quantities, then a precise statement of the uncertainty principle is[13]

$$\triangle p \, \triangle x \geq h/4\pi \tag{10}$$

i.e., the product of the measurement uncertainties cannot be less than $h/4\pi$. Another common form of the uncertainty principle is the statement that if the energy E of any system is measured, the uncertainty in this measurement, $\triangle E$, is related to the time $\triangle t$ taken to make the measurement by

$$\triangle E \, \triangle t \geq h/4\pi \tag{11}$$

The exact time at which the measurement is made must be uncertain by just the amount $\triangle t$.

Still another (and less common) example of the uncertainty principle is the statement that if a measurement is made on a sinusoidal signal, or on a harmonically oscillating system of any sort, such that the number of quanta n in the signal and also the instantaneous phase ϕ of the signal are measured, then the product of the errors obeys an uncertainty relationship given by[21]

$$\triangle n \triangle \phi \geq \frac{1}{2} \tag{12}$$

We will need this latter form of the uncertainty principle in discussing the minimum noise on a sinusoidal signal. Since this particular form does not seem to be discussed in the usual elementary introductions to modern physics, we will take a moment to relate it to more common forms. Consider as a concrete example of a harmonic oscillator a swinging pendulum with oscillation frequency f. The energy of this pendulum will be $E=nhf$, where hf is the energy of a single quantum and n is the number of quanta present in the oscillator. The instantaneous phase of the pendulum at time t (with respect to $t=0$) will be given by $\phi=2\pi$ ft. Now, attempting to measure the number of quanta n in the system to a precision $\triangle n$ means attempting to measure the pendulum's energy E to a precision $\triangle E=hf \triangle n$. But, according to the usual form of the uncertainty principle, Equation 11, this requires at least a length of time $\triangle t \geq h/4\pi \triangle E = 1/4\pi f \triangle n$. But, a time uncertainty $\triangle t$ in the measurement means an uncertainty in phase measurement given by $\triangle \phi = 2\pi f \triangle t \geq 1/2 \triangle n$. Therefore, the form $\triangle n \, \triangle \phi \geq 1/2$ of Equation 12 is equivalent to the commoner form of Equation 11.

Amplifier Bandwidth and Resolution Time

Before going on, we must also introduce the concept of the resolution time τ of an amplifier. There is a theorem of communication theory, the *sampling theorem*, which says that one can completely describe a band-limited signal of frequency bandwidth B by giving the instantaneous value of the signal voltage at any set of instants spaced by half the period of the highest frequency B. All of the information content of the signal is obtained by sampling it at intervals spaced by $\tau=1/2B$. Similarly, if a bandpass amplifier has a bandwidth B about some carrier frequency, then B is the highest modulation frequency which the amplifier will pass. The resolution time $\tau=1/2B$ is then essentially the time required for the amplifier to sense and report a change in the modulated carrier input to the amplifier. The amplifier can, in effect, make a new measurement on the incoming signal in each time interval $\tau=1/2B$. Therefore, we can refer to this time interval as the *resolution time* of the amplifier.

The Ultimate Amplifier Noise Limit

We are now ready to derive the minimum noise figure expression for a linear amplifier from the uncertainty principle. The argument given here comes from two very provocative papers written by H. Friedburg[4] and by R. Serber and C. H. Townes[14]. A precursor of many of their concepts is a much earlier paper by D. Gabor[5]. We will reproduce here essentially the argument given by Friedburg.

Friedburg proposes that we consider an amplifier which is capable of measuring the amplitude and phase of an incoming signal. The signal is probably most easily visualized as a narrowband modulated carrier, so that we can think in terms of measuring the energy and phase of the nearly sinusoidal carrier wave. (The phase must be measured with respect to some reference. This reference may either be the original source of the signal, as in a phase-sensitive amplifier, or it may be a local oscillator at the same frequency, as in a superheterodyne receiver). Let the incoming signal voltage be separated into an in-phase component v_1 and a quadrature or 90°-out-of-phase component v_2. For simplicity, let v_1 and v_2 be normalized voltages, normalized in such a way that the power level of the input signal and its instantaneous phase are given by

$$P = v_1^2 + v_2^2$$

$$\phi = \tan^{-1}(v_2/v_1) \tag{13}$$

Then, the number of signal quanta n arriving during one resolution time τ of the amplifier is given by

$$n = \frac{P\tau}{hf} = \frac{v_1^2+v_2^2}{2\,hfB} \tag{14}$$

We will view the amplifier as a device which measures this number n and also the instantaneous phase ϕ (or at least which amplifies the signal up to a level where these quantities can be measured). Now, if there is any noise in the amplification process, this will add an uncertainty $\triangle v_1$ to the signal v_1 and similarly will add an uncertainty $\triangle v_2$ to v_2. This will result in uncertainties $\triangle n$ and $\triangle \phi$ in the measurement of n and ϕ, given by

$$\triangle n = \frac{v_1 \triangle v_1 + v_2 \triangle v_2}{hfB}$$

$$\triangle \phi = \frac{v_1 \triangle v_2 - v_2 \triangle v_1}{v_1^2 + v_2^2} \tag{15}$$

It makes the following mathematics much simpler, and leads to no errors, if we assume that the noise uncertainties or noise fluctuations $\triangle v_1$ and $\triangle v_2$ have the same rms value $\triangle v$ and that there is no correlation between $\triangle v_1$ and $\triangle v_2$. It also simplifies matters to assume that the signal voltages v_1 and v_2 have the same value v. The mean-square uncertainties in n and ϕ then become

$$\triangle n^2 = \frac{v_1^2 \triangle v_1^2 + v_2^2 \triangle v_2^2}{(hf\,B)^2} = \frac{2v^2 \triangle v^2}{(hf\,B)^2} \tag{16}$$

$$\triangle \phi^2 = \frac{v_1^2 \triangle v_2^2 + v_2^2 \triangle v_1^2}{(v_1^2 + v_2^2)^2} = \frac{\triangle v^2}{2v^2}$$

These are the mean-square uncertainties which will result if the amplifier adds any noise fluctuations $\triangle v^2$ to the incoming signal. Multiplying these uncertainties together and using the uncertainty principle of Equation 12 — which, remember, is a basic law of physics and must be obeyed — we obtain

$$\triangle n^2 \triangle \phi^2 = \frac{(\triangle v^2)^2}{(hfB)^2} \geq \frac{1}{4} \tag{17}$$

or

$$\triangle v^2 \geq \frac{1}{2}\, hf\,B \tag{18}$$

The result is, in short, that the noise voltage fluctuations $\triangle v^2$ added by the amplifier to both the in-phase and quadrature voltages cannot be less than this value. If the noise voltages were less than this, it would be possible to measure the signal voltage with the amplifier to a precision better than the uncertainty principle will allow. *The amplifier must have at least this minimum amount of noise.* Converting these noise voltages to noise power according to Equation 13, we can say that the amplifier inevitably adds to the signal a noise power P_n given by

$$P_n = 2 \triangle v^2 \geq hfB \tag{19}$$

where the factor of two comes from the in-phase plus quadrature components.

One can argue, if he likes, that this uncertainty is an inherent property of the incoming *signal* itself, not a property of the *amplifier.* It seems equally valid, however, to take the alternative viewpoint, as we do here, that every amplifier has an inherent noise which is introduced in the amplification process, thus preventing measurement of any signal to greater precision than the uncertainty principle will allow.

This choice of viewpoints, as to whether the uncertainty fluctuations are to be assigned to an inherent property of the signal or of the amplifier, is not really a significant choice. The only thing we can directly observe is the outcome of the measurement performed on a signal by an amplifier. The uncertainty principle asserts that there will always be an uncertainty in this experimental outcome. We can say either that this is a property of the signal or that it is a property of the amplifier. There is no way, however, for us to pull apart the experiment and see whether the uncertainty comes from the signal being measured or from the apparatus doing the measuring. The signal and the measuring apparatus are not separable, but form a single indissoluble system, to which the uncertainty principle applies.

The noise power P_n above is the equivalent noise input power to the amplifier. We can relate this to an equivalent input noise temperature T_a of the amplifier in the usual way, by writing

$$\begin{pmatrix}\text{Equivalent}\\ \text{Noise Input}\end{pmatrix} = \frac{hf\,B}{e^{hf/kT_a} - 1} \geq hf\,B \tag{20}$$

The equivalent noise input is more commonly written as simply kT_aB. However, since quantum limits are involved here we have used the more exact quantum form for thermal noise. Simplifying this expression, we find that equivalent input temperature T_a for any amplifier cannot be less than the ultimate lower limit

$$T_a \geq (ln\, 2) x \left(\frac{hf}{k}\right) \tag{21}$$

The minimum value of amplifier noise temperature, according to this result, is directly proportional to frequency. At f = 10,000 Mc/s, for example, the limiting value is $T_a > 1/2$°K. On the other hand, at the frequency of visible light, the minimum value is $T_a \sim 25{,}000$°K, which makes a coherent light amplifier look like a rather noisy device.*

Minimum Noise Figure of a Maser Amplifier

The maser amplifier is one specific case where the ultimate noise figure limitation can be directly verified, as we will now show. In Part II of these articles an equivalent circuit and formulas for noise in a maser crystal were given. If these results are reviewed, it is easily found that a general expression for the noise output from an amplifying maser is

$$\text{Noise output} = \frac{(G-1)\, hf\,B}{1 - \exp\,(-hf/kT_m)} \tag{22}$$

where losses have been set equal to zero and only the spin system noise included. The quantity T_m is the magnitude of the negative spin temperature which characterizes the population distribution on the maser's signal transition.

The assumption usually made at this point is that $hf/kT_m << 1$, which leads to the familiar result

$$\text{Noise output} \approx (G-1) kT_mB, \quad hf/kT_m << 1 \tag{22a}$$

However, if instead the reverse condition $hf/kT_m >> 1$ holds, either because of very high frequency f or very low temperature T_m, then the result is

$$\text{Noise output} \approx (G-1) hfB, \quad hf/kT_m >> 1 \tag{23}$$

Figure 3 shows the transition from one case to the other. The case $T_m \rightarrow 0$ corresponds to a 'perfect' maser, and so a perfect maser obviously obeys the ultimate noise figure limitation.

It is instructive to examine in more detail the source of this unavoidable noise limit in a maser. Figures 4(a)

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* *Note that the author has been careful to hedge his bets here by stating only that a coherent light amplifier will be very noisy by microwave standards. This does not shed any light on more meaningful questions such as the information handling capabilities of a coherent light amplifier, or the relative merits of a coherent optical amplifier and a quantum counter. Note also that Weber (Reference 17) has suggested the "noise number" N_n as a good measure of amplifier noise. The noise number is the number of input photons per amplifier resolution time which will double the noise power output of an amplifier. The noise number of an ideal maser is one, independent of frequency. However, the energy of one optical quantum is a good deal larger than the energy of one microwave quantum*

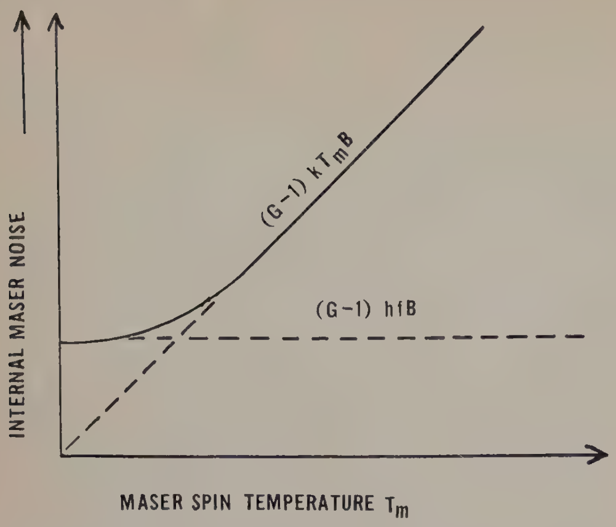
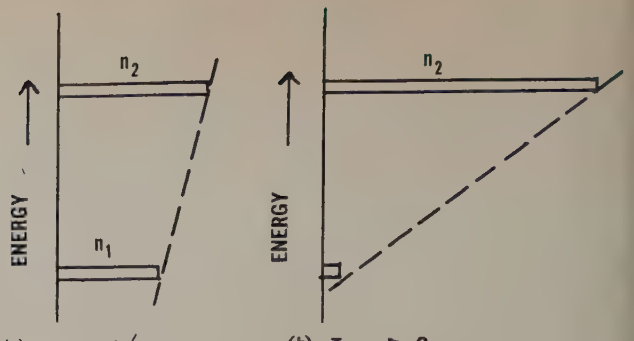


Figure 3 — The internally generated noise of a maser amplifier vs. the maser spin temperature T_m. Even a 'perfect' maser ($T_m \rightarrow O$) has a finite noise output.

and (b) show the populations of the upper and lower levels of the maser's signal transition in the two cases (a) when the spin temperature magnitude T_m is fairly large, so that $hf/kT_m << 1$, and (b) when $T_m \rightarrow 0$, so that $hf/kT_m >> 1$. We recall that the noise generation in a maser spin system is basically due to spontaneous emission from the upper level to the lower, and that the equivalent noise voltage due to this spontaneous emission is directly proportional to the population n_2 in the upper level only. We also recall that the amount of negative resistance exhibited by the spin system is directly proportional to the population *difference*, $n_2 - n_1$, between the upper and lower levels.

Now, in the large T_m case, the populations of the two levels are essentially equal, although there is slight surplus of spins in the upper level. Hence, the noise voltage is $\sim N/2$, where N is the total number of spins in the two levels. In this region, if T_m is decreased somewhat, the chief effect is to increase the small population difference $n_2 - n_1$ proportionately, without changing either n_1 or n_2 by very much. Hence the amount of negative resistance increases proportionately, but the noise voltage remains at $\sim N/2$. The noise figure of the maser is improved because there is now more negative resistance for the same amount of noise voltage.

If T_m is reduced enough to pass over into the small T_m condition, however, as in Figure 4(b), then eventually the negative resistance reaches its maximum possible value, when $n_2 - n_1$ becomes just N. At the same time, the noise voltage increases to become $\sim N$. The negative resistance, the noise voltage, and the noise figure all reach limiting values. In this condition, which corresponds to the best possible maser operation, there are still spins in the upper level — in fact, all the spins are in the upper level. Therefore, there will be spontaneous emission noise in the maser amplifier. Since spontaneous emission is a very basic and fundamental process, which cannot be turned off or inhibited by any known means, it appears that this noise sets the absolute lower limit to maser amplifier noise figures. As we noted above, this lower limit due to spontaneous emission agrees exactly with the lower limit predicted by the uncertainty principle for any type of amplifier. Therefore, perhaps we can say that we have some insight into the meaning of the ultimate noise figure limit, at least for the maser case.



(a) $T_m >> hf/k$ (b) $T_m \rightarrow 0$

Figure 4 — Populations of the maser signal levels in the two cases.

Zero-Point Energy

We will now consider the ultimate noise figure limit, particularly in the maser case, from still another viewpoint, using the concept of *zero-point energy.*

We must first define what this term means. If one carries out a rigorous quantum-mechanical analysis of a harmonic oscillator, or a quantum-electrodynamical analysis of the electromagnetic field, one finds that the energy E of a harmonic oscillator, or of a mode of the electromagnetic field, can only take on the values[13]

$$E = (n + \frac{1}{2})\, hf, \quad n = 0, 1, 2, \ldots \tag{24}$$

In other words, the energy can only change in steps of the size of one quantum hf. However, the somewhat surprising feature is that the minimum energy of such an oscillator or mode, even when no quanta are present, is still 1/2 hf, i.e. one-half of a quantum. This additional half-quantum is referred to as the *zero-point energy* of the quantum system.

If this zero-point energy is present, it apparently should be added to the thermal noise and blackbody-radiation formulas given in Part I of these articles. The noise power carried by a propagating system should apparently be written as

$$P_n = \frac{hf\,B}{\exp\,(hf/kT) - 1} + \frac{1}{2}\,hf\,B \tag{25}$$

and the blackbody radiation density should apparently be written as

$$= \frac{8\pi\,hf^3\,B}{c^3}\left[\frac{1}{\exp\,(hf/kT) - 1} + \frac{1}{2}\right] \tag{26}$$

The second term in both cases is the zero-point energy, which is independent of temperature.

However, there is an important condition to these statements. The zero-point energy is not *removable* from an oscillator or a mode. The integer n in Equation 24 cannot go negative. Except for the special interpretation given in the following paragraph, we can say that *the zero-point energy does not interact with the rest of the world. In particular, the electromagnetic fields of this energy do not act on charged particles.*[13] Therefore, we do not really need to include this zero-point energy in calculations since, although it may be present, it will have no effects.

There is one reason why one might choose to retain the zero-point energy in calculations. If one wishes, one can make a formal identification between the zero-point energy and the process of spontaneous emission which we introduced in Part II. We recall the statement made in Part II that when an electromagnetic signal is applied to a quantum system at the transition frequency between two levels, the system is caused to make *stimulated* jumps or transitions between the levels, in both upward and downward direction. We also said that *spontaneous* transitions occurred without any applied signal, but only in the downward direction.

If the theory of spontaneous emission is examined in detail, it can be shown that the rate of spontaneous transition in any quantum system is just equal to the downward transition rate that would be stimulated by applying a signal with a radiation density of one quantum per available mode. Now, the zero-point energy is always present, at least according to the mathematics of the quantum theory, and it has a radiation density of one-half quantum per available mode. Therefore, a formal relationship between the two can be established by saying that the *zero-point energy causes the spontaneous emission.* If this relationship is to work out right, we must also postulate that (a) *the zero-point energy can stimulate transitions in a quantum system, but only in the downward direction;* and (b) *the zero-point energy is twice as effective as ordinary energy in stimulating these downwards transitions.*[13]

If we make this identification, then we can carry along the zero-point energy, and use it as a rather convenient way to derive the amount of spontaneous emission. However, we can equally well forget about zero-point energy and simply take spontaneous emission as a recognized physical process. What we must *not* do is attempt to add together zero-point energy and spontaneous emission as two different processes.

Deriving the Maser's Noise Figure from Zero-Point Energy

If maser noise basically results from spontaneous emission, and if spontaneous emission and zero-point energy are closely related, then it should be possible to obtain maser noise directly from zero-point energy. This has been pointed out previously by a number of different authors, particularly Takahasi, Shimoda and Townes.[4,14,19] The following is a relatively simple way of obtaining the noise figure of a maser using the concept of zero-point energy.[20]

We consider a maser with populations n_2 and n_1 in its upper and lower signal-frequency energy levels. Suppose that an input signal of power level P_s is sent into the input port of the maser. This power will stimulate transitions between the two levels, and cause an amplified power output from the maser. The power output from the maser will consist of the power input plus the power added to the input by the maser crystal due to stimulated transitions. The amount of power added due to stimulated transitions will be proportional to the number of spins in the upper minus the lower levels, times a transition probability W which will be proportional to the applied signal level. In other words

$$\begin{aligned}\text{Added power} &= W(n_2-n_1)\\ &= K(n_2-n_1)P_s \end{aligned}\qquad (27)$$

and

$$\begin{aligned}\text{Signal output} &= P_s+K(n_2-n_1)P_s\\ &= G\,P_s \end{aligned}\qquad (28)$$

where K is a constant which depends on geometry, spin density, transition-probability matrix elements, and similar factors. We obtain

$$K=\frac{G-1}{n_2-n_1}\qquad (29)$$

from Equation 28.

Now, we assume for simplicity that the maser has no internal losses. We do not put in any spontaneous emission since we will use zero-point energy instead. However, we do assert that the noise input from the source or generator to the maser has the form

$$\text{Noise input}=\frac{hf\,B}{e^{hf/kT_g}-1}+\frac{1}{2}\,hf\,B\qquad (30)$$

The first term is the thermal noise from the source or generator impedance, which, as usual, we do not count against the amplifier. However, the second or zero-point energy term we count as an additional noise source, which will act on the maser spin system in the special fashion described earlier. That is, it will cause only downward transitions, and will be twice as effective as an ordinary signal in causing these. Therefore, the noise power output from the maser due to transitions caused by the zero-point energy input will be

$$\text{Noise output}=Kn_2\cdot\frac{1}{2}\,hf\,B\qquad (31)$$

where this K will be the same as the K in Equation 27. Using Equation 28, we can put this equation into the form

$$\begin{aligned}\text{Noise output} &= (G-1)\,\frac{n_2}{n_2-n_1}\,hf\,B\\ &= (G-1)\,\frac{1}{1-\exp(-hf/kT_m)}\,hf\,B \end{aligned}\qquad (32)$$

where we have also used the definition of spin temperature, $n_1/n_2=\exp\ (-hf/kT_m)$, from part II. But, Equation 32 is simply the standard expression already given for the noise output from a maser. We see from this derivation that this noise output can be viewed as being due entirely to the amplification of zero-point energy by the maser.

The zero-point energy has the peculiar property of causing only downwards transitions. If the maser is a perfect maser, having all its spins in the upper level, then signal and zero-point energy are amplified equally, except for a factor of two. The maser's noise output is the minimum value, $(G-1)\,hfB$. If the maser is not perfect but has some spins in the lower level also, then a signal is not amplified as effectively as is the zero-point energy, because the signal causes upward as well as downward transitions. As a result, the relative strength of the noise is enhanced, in a fashion that depends on the relative level populations and hence the maser's spin temperature in just the proper way.

Other Amplifiers

The maser amplifier is one specific case where we can show directly just how the ultimate noise figure limitation arises, and what the source of the noise is. It would be interesting to have equally direct verifications of the ultimate noise figure limitation in other specific cases, such as the parametric amplifier, the tunnel diode, the triode, or the traveling-wave tube. However, the lower limit on amplifier noise figure does not seem to be as easily obtained in these cases as in the maser case.

In fact, according to simple theories most of these amplifiers have no lower bound on their noise figure. The parametric amplifier's noise figure, for example, is predicted to become arbitrarily small if the idler tank is cooled to low enough temperatures. There is no apparent lower bound on the noise figure of a traveling-wave tube if low-velocity drift spaces or velocity sorting techniques are used. The tunnel diode noise figure can be reduced indefinitely if the valley current is made small enough. Obviously, all of these simple theories become invalid and must be extended when the noise figure is lowered to near the ultimate lower limit.

The preceeding discussion of zero-point fluctuations seems to offer a promising starting point for finding the minimum noise figure of these other amplifiers. The same zero-point energy input which we used to derive the maser's noise figure is, of course, also present in the input to every other type of amplifier. Moreover, every other type of amplifier can also be described in terms of energy levels, stimulated transitions, and so on, as is the maser. This is not normally done, since it is much easier to describe these other amplifiers in purely classical terms. The energy-level structure of most of these other amplifiers is rather complicated to describe, involving a continuous spectrum of energy levels and so forth. But, the world around us is fundamentally a quantum rather than a classical world if examined closely enough, and every amplifier is necessarily a quantum-mechanical amplifier on a small enough scale.[17]

In these other amplifiers, then, the same conclusions as for the maser may still apply. That is, an input signal quantum may be said to induce upward and downward transitions among the (probably complicated) energy levels of the amplifier. The amplification depends on the excess of downward over upward transitions. The zero-point energy input will still induce only downward transitions (with double efficiency). The best possible case is when the signal also can induce only downward transitions. The equivalent noise input then has its minimum value of hfB. In any other case, the effective gain for the zero-point energy input will be larger than the signal gain, and the noise will exceed hfB.

It is not at present apparent to the author how to carry out a detailed calculation based on this approach for any of the other amplifiers listed above, although he has made some progress on a quantum analysis of parametric amplification. It would be nice to know if these other amplifiers can also reach the ultimate limit, or if some of them are inherently more noisy.

Note the interesting side point that by classical standards the maser is a more complicated amplifier than others, since it can be satisfactorily described only by invoking quantum ideas, whereas most other amplifiers can be quite satisfactorily described in purely classical terms. However, once one does invoke quantum ideas the maser suddenly becomes the simplest possible amplifier. It becomes easiest to describe because of its simple discrete energy-level structure, while the other amplifiers become extremely complicated and difficult to handle.

Since this article was written the author has completed a quantum analysis of the parametric amplifier. The results of this analysis for the ordinary parametric amplifier are that there is a spontaneous emission noise in the amplifier, caused by spontaneous emission of quanta from the pumping source into the signal and idle tanks. Under certain circumstances, the parametric amplifier can reach essentially the same ultimate lower noise limit as the maser; under other circumstances, the parametric amplifier is substantially noisier. In addition, the analysis shows that the parametric upconverter type of amplifier is fundamentally different, having no spontaneous emission or randomness in its behavior. In the upconverter, the pump serves essentially to transfer signals back and forth between the lower and upper frequency tanks in a periodic fashion, with no inherent noise associated with this process. This analysis will be published at a later date.

More Rigorous Treatment of Amplifier Noise

The discussions above have all implicitly assumed that the noise in a maser (or other amplifier) consists of additional noise power which is simply *added* to the signal power. This assumption of simple additive noise is, however, not truly correct. We will attempt to point out here what a more correct description is. The following rigorously correct description of amplifier noise has been given by Shimoda, Takahasi, and Townes.[19]

Suppose that the signal input to an amplifier consists of a certain number n_1 of photons or quanta. Then, the output from the amplifier will be some larger number n_2 of photons. Roughly speaking, the number of output quanta will be larger than the number of input quanta by just the power gain of the amplifier, i.e. $n_2 \approx G\, n_1$. However, strictly speaking this is true only on an average basis. If one repeats the experiment of sending in n_1 input quanta a number of times, the exact number of output quanta n_2 will fluctuate randomly from time to time. The number n_2 will be a random variable with an average value near Gn_1, but with random fluctuations about that value. This random fluctuation of the number of output quanta, given a fixed number of input quanta, is the true form of noise fluctuations in an amplifier. Note that this is neither simple additive noise nor is it multiplicative noise.

To properly describe these fluctuations in an amplifier, one must find the probability distribution $P(n_2;\, n_1)$ for that amplifier: that is, the probability that the number of quanta out will be n_2, given that the number of quanta in is n_1. This probability distribution, which is in general a complicated function of n_1, n_2, and the properties of the amplifier, has been worked out in detail for maser amplifiers by Shimoda, Takahasi and Townes. A rigorous treatment of fluctuations in maser amplification then becomes a problem in statistics, with $P(n_2;\, n_1)$ as the rigorous description of the maser amplifier itself.

Shimoda, Takahasi and Townes show, among other things, that the probability $P(n_2;\, n_1=0)$ is not zero, even for a perfect maser; i.e., there are in general some output photons, $n_2 \neq 0$, even when there are no input photons, $n_1=0$. This output with no input we would call noise, although it is not simple additive noise. Another result is that the *average* number of output photons from a perfect high-gain maser is given by $n_2 = Gn_1 + (G-1)$, The first term of this we would call amplified input; the second term we would again call noise. Since the energy of one photon is hf, and since our results above are that the equivalent noise input for an amplifier is just one photon per resolution time, the second term corresponds very closely to the limiting noise value (G−1)hf B.

A Noiseless Detector: the Quantum Counter

We turn now to a quite different type of low-noise device. Several people have pointed out that it is perfectly possible, at least in principle, to build a radiation detector which will receive and amplify incident radiation quanta without spontaneous emission or any other kind of noise. Such devices can be lumped under the heading of *quantum counters.* Whether or not they should be referred to as *amplifiers* is a matter of definition — certainly they must be distinguished from linear, phase-preserving 'voltage' amplifiers.

A simple example of a quantum counter is an ideal photocell or photomultiplier tube. In an ideal phototube, the cathode would be operated at a temperature approaching absolute zero, so that the 'dark current' caused by thermal emission from the photo-cathode would be vanishingly small. Of course, a cathode can never be cooled all the way to absolute zero, but it can, at least in principle, be cooled arbitrarily close to absolute zero; and hence the dark current can be made arbitrarily small. Thus, there would be essentially zero output in the absence of signal. At the same time, in a perfect phototube every photon falling on the cathode would liberate an electron and cause an output pulse. Therefore, the device would be a perfect photon detector.

There are a number of different types of photocells, photoconductors, and the like, which operate in the general fashion described here. The Geiger counter is basically such a device. As a practical fact, some of the photodevices presently available in the infrared and optical ranges and above approach very closely to the idealized behavior just described.

Bloembergen[1] and Weber[17] have recently proposed other quantum counters which are maser-like in appearance, but which are basically photon detectors of the type just described. The device proposed by Bloembergen, for example, would use the energy-level scheme shown in Figure 5. The system would be cooled to a low enough temperature so that hf/kT was $<<1$ for all of the transition frequencies involved. Under this condition, all of the spins would be frozen into the lowest or ground level, with essentially no spins at all in the higher levels. A 'pump' signal would be continuously applied at the 2-3 transition frequency as shown. If a photon at the 1-2 transition frequency were applied to the system, it would be absorbed by a spin in the lowest level, this spin being thereby lifted into level 2. The pump would then immediately lift this spin into level 3. The energy levels used would be chosen such that a spin lifted into level 3 would very rapidly drop back to level 1 by spontaneous emission, thereby emitting a photon at the 3-1 transition frequency. Thus, the input of a 1-2 quantum would cause the output of a 1-3 quantum having a much higher frequency and hence a much higher energy. Thus, the device amplifies the quantum's energy, at least in a sense. Moreover, in the absence of signal there would be no spins in the topmost level, and hence absolutely no output due to spontaneous emission. The similar devices proposed by Weber would have the same advantages.

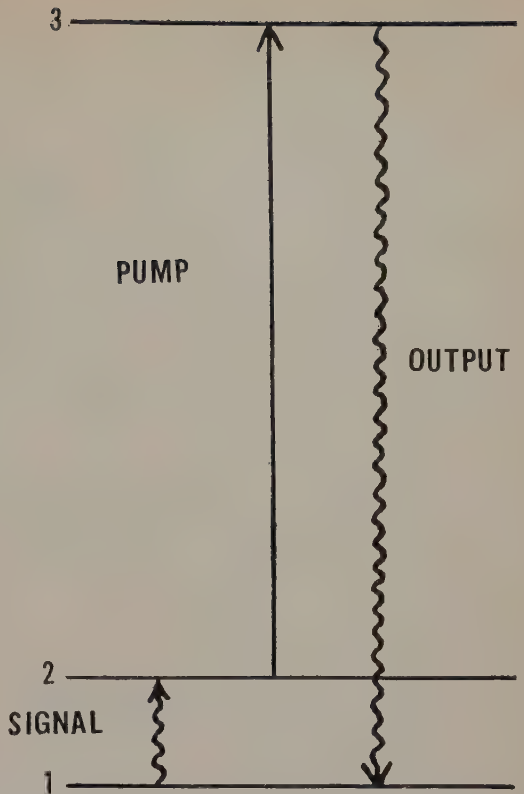


Figure 5 — The quantum counter scheme proposed by Bloembergen.

The type of counter proposed by Bloembergen and Weber would be very useful in detecting far-infrared photons, for which there are no good detectors presently available, by converting the far-infrared photons into visible photons, for which excellent photodetectors are available. No quantum counter of this type has as yet been demonstrated experimentally, although the general principle seems to hold considerable promise.

A Broadened Interpretation of the General Noise Limit

The quantum counter, with its total lack of noise output, may appear to circumvent the ultimate noise limit imposed on linear phase-preserving amplifiers by the uncertainty principle. As Serber and Townes[14] point out in detail, however, this is not really the case. The noise limitation on any sort of detector or measuring apparatus is, in its most basic form, the statement that $\triangle n \triangle \phi \geq 1/2$. Various sorts of detectors approach this limitation in different fashions. For example, if the number of quanta in an input signal is n, Equations 13, 14 and 16 for the linear voltage amplifier can be manipulated to show that the uncertainties in n and ϕ are given by $\triangle n = n^{1/2}$ and $\triangle \phi = (2n)^{-1/2}$ when measured by an ideal amplifier of this type.* On the other hand, if the measurement is made by a quantum counter, then $\triangle n \rightarrow 0$ in the ideal case; but $\triangle \phi \rightarrow \infty$ since no phase information whatever is obtained. Serber and Townes show how another type of detector might be constructed which would go to the opposite extreme: it would be an ideal phase detector, measuring phase with error $\triangle\phi\rightarrow 0$, but in the process destroying any possibility of measuring the number of quanta n and so making $\triangle n\rightarrow\infty$.

---

* *This brief discussion glosses over the non-trivial question of how one even defines the phase of an electromagnetic wave when the signal level is so low that only a small number of quanta are present.*

Serber and Townes also study the question of whether one can foil the $\triangle n\triangle\phi > 1/2$ limitation by sending a signal into a tee junction which divides the signal in half. One half might go to an ideal quantum counter, the other half to an ideal phase detector. Knowing that exactly half the signal was sent to the quantum counter, plus the number of quanta counted by the counter, one could apparently learn the number of quanta in the original signal with arbitrary precision; and similarly for the phase. However, this is not the case. There is a kind of 'partition noise,' in both phase and amplitude, associated with the process of splitting up the signal at the tee junction, so that there is an inherent uncertainty in the instantaneous fraction received by each of the two arms. If this is taken into account in detail, the total uncertainty in the signal measurement will still always satisfy $\triangle n\triangle\phi\geq 1/2$.

Channel Capacity and Noise

As a final comment, we reemphasize that the noisiness of a communications system is not necessarily significant by itself. The basic problem we are usually interested in is transmitting information through a communications channel. Noise is significant because it limits the amount of information which can be sent through a channel using a specified amount of signal power. According to the results of Shannon,[15] the maximum rate of information transfer through a channel of bandwidth B having Gaussian noise power P_n, using an average signal power P_s, is

$$C=B\log_2(1+P_s/P_n) \qquad (33)$$

where C is the *channel capacity* measured in binary digits or bits per second.

As Pierce has pointed out,[12] this formula is entirely classical in its derivation. It is to be expected that when quantum effects become significant, as will happen at low signal levels — i.e., when the number of quanta n in a signal is small — then this formula will have to be modified. A statistical approach to this problem has been taken by Stern in two recent papers[18] which supply some but not all of the desired answers.

We will quote only one of Stern's results. We have noted above that in a maser or any other similar amplifier, the number of output quanta for a given input is not absolutely determined, but is only statistically related to the input. In other words, even with a fixed input, there is a certain uncertainty or indeterminancy in the output. This amounts to a loss or destruction of some of the information content of the signal. In fact, Stern shows that *in any high-gain maser-like amplification process at least half of the information content of a signal is destroyed.* Of course, in most practical systems at the present time we do not use anything approaching half of the potential information content, which makes it possible to transmit a smaller amount of information with a much higher reliability than 50 per cent. Nonetheless, at least 50 per cent of the potential information content of a signal is destroyed in any high-gain amplification.

Even including Stern's work, there apparently does not exist as yet any general sort of formula comparable to Equation 33, which will give the channel capacity taking quantum effects into account. This being the case, our discussion of ultimate quantum limits on amplifier noise figure can not at this time be brought to a fully satisfactory conclusion. We may have some idea of quantum noise limits on the amount of noise, but it is not yet possible to relate this to the more important factor of information channel capacity. Hopefully, this problem will be solved soon by the information theorists.

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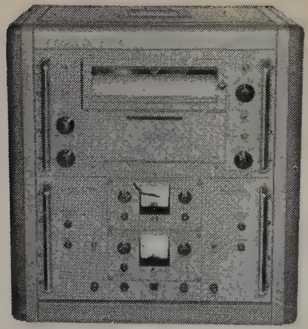
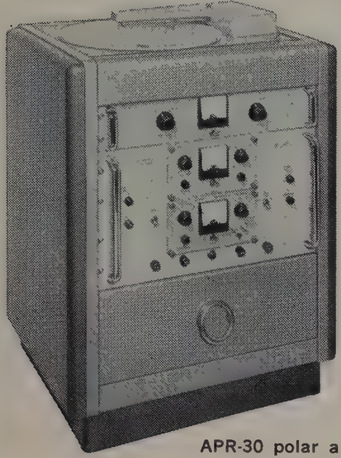
Flexibility and Refinement



APR-20 rectangular antenna pattern recorder



APR-30 polar antenna pattern recorder

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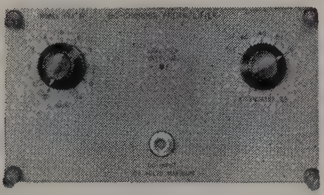
It's the little things that make the difference. Little things, refinements, "extras," and top-notch workmanship all add up to preference for S-A instrumentation.

Things Like Plug-In Balancing Potentiometers...

Series P plug-in pen balancing potentiometers

Series P potentiometers are used in both rectangular and polar coordinate pattern recorders. By interchanging potentiometers together with the appropriate pen function amplifier, different responses—linear, square-root, and logarithmic—are obtained. Interchanging these new self-aligning potentiometers can be accomplished in less than thirty seconds. Stocking spare units cuts downtime. Of dust and dirt proof construction, Series P plug-in balancing potentiometers are offered with exchange pricing.

DC Amplifiers...



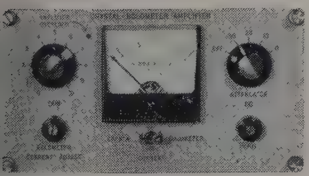
DCA-21 amplifier for dc input signals

Scientific-Atlanta's DCA-21 amplifier lets APR 20/30 recorders accept dc input signals. A narrow band amplifier preceded by an electromagnetic chopper, the sensitive DCA-21 has a linear dynamic range of 80 db. The unit is directly interchangeable with Series CBA-20 Crystal-Bolometer amplifiers.

Recorder Pen Programmers...

Up to five different pen writing codes can be selected by adding the Model RPP-1 Recorder Pen Programmer to an APR 20/30 installation. Compact, lightweight, and rack mounted, the programmer provides solid line, dot, dash, dash-dot, and space-dot-dot codes at an adjustable code rate of 30 to 90 cycles per minute.

Crystal Bolometer Amplifiers...



High gain, low noise crystal-bolometer antenna

Sensitive, narrow-band Crystal-Bolometer amplifiers are miniaturized units designed for use as preamplifiers in S-A polar and rectangular pattern recorders. Five models, CBA-21 through CBA-25 are available. Features include bolometer burnout protection, low noise figure, triaxial signal ground return, up to 108 db gain, 80 db linear dynamic range, adjustable bandwidth (CBA-23), high rejection (CBA-24), variable center frequency (CBA-25).

Modification C, Chart Compression...

Modification C, which must be ordered at the time of recorder purchase, provides both standard and compressed cycle charts from a single APR 20 Rectangular pattern recorder. Standard chart cycle is 20 inches, compressed 8 inches. Compressed recordings are conveniently sized to fit standard 8½ x 11 notebooks and reports.

Chart Paper, Recording Pens, Ink, and Accessories...

Scientific-Atlanta offers its customers one-day service by stocking, for immediate delivery, a wide variety of chart paper, recording pens, and other recording necessities.

But above all, it's the engineering philosophy of a company run by antenna engineers for antenna engineers.

Call your nearby S-A engineering representative for more information on S-A pattern recorders and accessories. For complete technical information, please write to Box 69

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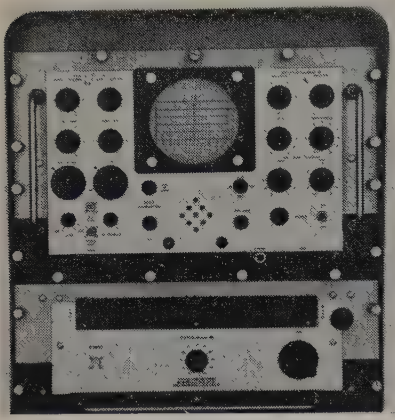
Circle Reader Service Card 60

New Products

SPECTRUM ANALYZER FEATURES WIDE OPERATING FREQUENCY RANGE



LA-21 Spectrum Analyzer from Lavoie Laboratories, Inc., Morganville, N. J., is designed specifically to cover the most widely used communication frequencies in applications including spurious response evaluation, signal stability tests, spectrum monitoring, and filter network evaluation.

The LA-21 features a wide operating frequency range of 10 to 1180 Mcs in conjunction with very narrow resolution and high sensitivity. This enables the operator to evaluate a large number of signals with widely differing characteristics within the frequency spectrum.

Another feature of the LA-21 is its ability to discriminate between signals separated in amplitude by as much as 80 db, and by as little as 50 KC in frequency, and by as much as 90 db at 150 KC separation. This unit permits investigation of the spurious and harmonic content of signal sources within the frequency range of the analyzer.

A built in 100 KC and one Mc crystal controlled calibrator provides precise markers which allow calibration of the viewing screen at any spectrum width setting. This allows precise measurement of the frequency of any signal viewed on the cathode ray tube.

Circle Reader Service Card 101

—*mwj*—

RCA ANNOUNCES LINE OF PACKAGED MICROWAVE CIRCUITS

PARAMETRIC
AMPLIFIER

The first five members of a new family of packaged microwave circuits for satellite communications systems, military radar, L- and S-band communications have been announced by the RCA Electron Tube Division, RCA, New York, N. Y.

The units are packaged microwave circuits incorporating the newest tunnel and varactor diodes of the company's Semiconductor and Materials Division.

These solid-state microwave oscillators and amplifiers are expected to open new possibilities for miniaturization, improved systems reliability, and system cost reduction.

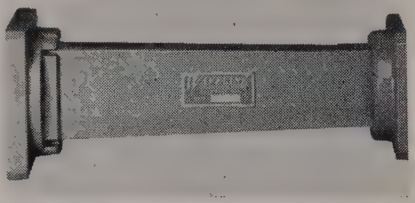
The new packaged microwave circuits include: the SS-100 Mechanically Tunable Tunnel Diode Oscillator, the SS-107 Fixed-Tuned Tunnel-Diode Oscillator, the SS-500 Tunnel-Diode Amplifier, the SS-1000 Helix Parametric Amplifier and the SS-1002 Low-Noise Parametric Amplifier.

The new microwave products are available standard prototypes now in pilot production to fill existing orders. Variants can be made to fill a wide variety of specifications. These items can be delivered in 30 to 90 days, the price being dependent upon specific customer requirements.

Circle Reader Service Card 102

—*mwj*—

WAVEGUIDE TRANSITIONS AND ADAPTERS ANNOUNCED



Waveline, Inc., Caldwell, N. J., has announced a complete and varied series of waveguide transition and adapter sections. The transitions, also known as tapers, provide a means of connecting one waveguide size to another. In addition the adapters may be used in connecting different flange combinations in the same waveguide size.

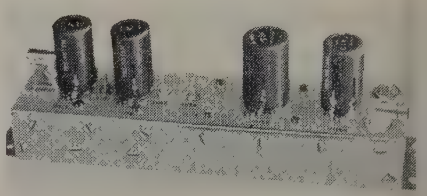
Available are transition sections that connect the standard military RG nomenclature waveguide to the standard commercial WR designated waveguide, as well as the normal transitions between waveguide in the military RG series and connection between the commercial WR series waveguide. Various Flange combinations (cover and choke) are included in the series of available transitions.

These standard units are normally furnished as silver plated brass assemblies with an instrument grey enamel finish. Aluminum versions are available for systems application use. Each unit is designed with a continuous taper section to provide a minimum VSWR characteristic and to optimize overall electrical performance.

Circle Reader Service Card 103

—*mwj*—

LEL ADDS TO MIXER-PREAMPLIFIER LINE



LEL, Inc., Copiague, L. I., N. Y., announces the addition of the IF42 AFC unit to its line of microwave mixer-preamplifiers and IF amplifiers.

Designed to control the frequency of a klystron local oscillator in pulse radar systems, the IF42, available at 30 or 60 Mc center frequencies, utilizes a diode-phantastron control circuit and has a sensitivity of 40 volts per megacycle.

Circle Reader Service Card 104

—*mwj*—

CORNING OFFERS MASSIVE RESISTORS FOR HIGH POWER APPLICATIONS

Massive resistors for high power applications are being offered in a standard line by Corning Electronic Components Corning, N. Y.

Five standard HL models — 12 to 72 inches long — have AC power ratings at 25°C of 250, 500, 1000, 3000 and 6000 watts. These ratings can be increased up to three times with forced air cooling, according to the Corning Glass Works department.

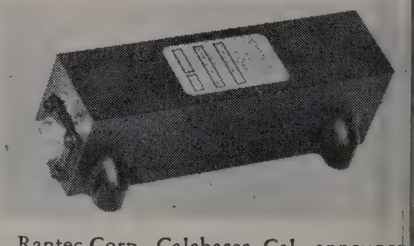
Applications include dummy antennas circuit loading and terminations. Becaus the HL resistors are film types and hav low reactance, they are ideal for circuit subject to steep voltage surges and saw tooth current patterns.

Under AC power, the H1 derating curv runs from 25°C to 225°C. Maximum su face temperature in operation is 270°C.

Circle Reader Service Card 105

—*mwj*—

BANDPASS FILTER DESIGNED FOR RUGGED MISSILE ENVIRONMENTS



Rantec Corp., Calabasas, Cal., announce a new bandpass filter for the 2200 Mc t 2300 Mc frequency band. Unit is ligh weight and designed for rugged missil

(*Continued on page 108*)

3 new Microwave Amplifiers designed by request

* 1 watt—12.4 to 18 Kmc

* 2 watts—8 to 12.4 Kmc

* 5 watts—7 to 11 Kmc

MICROWAVE AMPLIFIER

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- 30 db gain at rated power; flat response
- Compact, simple to operate
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- RF connectors out of front or rear

A number of Alfred's customers asked for—and now have—amplifiers with 1 and 5-watt outputs covering the ranges listed above. The new units can be used as broadband power amplifiers; stable power oscillators using external resonant feedback networks; narrowband amplifiers providing more than rated gain and power and for frequency multiplication. Each amplifier consists of a TW tube, its focusing magnet, and a completely regulated supply for obtaining optimum performance from the TW tube.

BASIC DATA	526	527	528
Frequency Range	12.4 to 18 Kmc	8 to 12.4 Kmc	7 to 11 Kmc
Power Output	1 watt	2 watts	5 watts
Gain (Small Signal)	30 db	30 db	30 db
Gain (Saturation)	25 db	30 db	30 db
VSWR (Input/Output)	2:1	2.5:1	2.5:1
RF Connectors	P Band Flange VG-419/U	Type N Female	Type N Female
Price	$4,950	$3,490	$3,490

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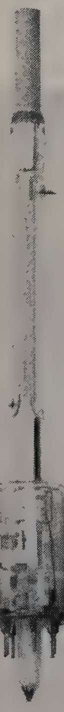
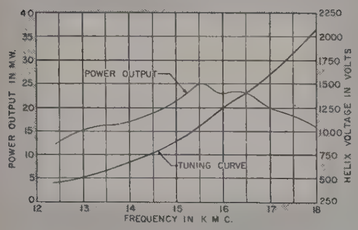


Oscillating at 18 kmc and delivering 15 milliwatts of power, a Stewart OD 12-18 BWO can be expected—and is **guaranteed**—to offer a minimum of 500 hours of high-performance service. In actual use, Stewart backward wave oscillators normally outlive their guarantees many times over.

Stewart BWOs offer particularly attractive possibilities as a source of microwave signals for microwave swept signal generators, and for receivers and transmitters requiring rapid programmed swept signal excursions, because of their excellent wide-band, electronic tunability characteristics. Performance curves for the OD 12-18 are shown here.



Whether or not you're interested in 3.24 x 10^{16} oscillations, we think you'll want to see a copy of the specification sheets for the complete line of Stewart BWOs. Drop us a note today.

STEWART ENGINEERING CORPORATION

SANTA CRUZ • CALIF.

Circle Reader Service Card 62

New Products

(Continued from page 106)

and satellite environments up to 20 g's from 25 to 3000 cps.

Insertion loss is 0.25 db in passband and 50 db in stopband. VSWR is less than 1.2:1, and filter can handle 15 watts of power CW at any altitude without corona. Size is approximately six inches by two inches by two inches, and weight is approximately 14 ounces.

Model FS-205 is available on 30 day delivery, and the price is $250 to $400 each in small quantities, depending on particular specifications and applications.

Circle Reader Service Card 106

—mwj—

FXR INTRODUCES FERRITE MODULATOR

FXR, Inc., Woodside, N. Y., has developed an absorption type ferrite modulator, Model X158A, that covers the full X band of 8.2 to 12.4 kMc.

The ferrite modulator is useful in precision microwave measurements, for the X158A produces true amplitude modulation with negligible frequency modulation. It is also applicable in communications systems for, by biasing the control solenoid, distortion free modulation is attained. Other applications include use as a square-wave chopper, a microwave switch and as a variable attenuator.

The Model X158A is composed of a ferrite bar mounted in a waveguide section. The waveguide and other structural parts are formed from fiberglass to eliminate the shorted-turn effect and eddy current losses. For microwave measurements where an undistorted waveform is not necessary, the applied audio frequency need only be one-half that of the desired RF response.

Circle Reader Service Card 107

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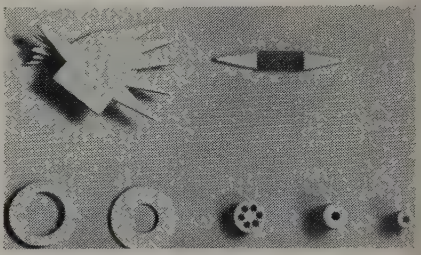
CUSTOM COMPONENTS OFFERS HI TEMP DIELECTRIC MATERIAL



A high temperature dielectric material, available in rods and sheets, has been announced by Custom Components, Inc., Caldwell, N. J. It is designated CMD-3048.

The material is usable for continuous operation at temperatures as high as 400°F, with a loss tangent less than .001 from 20 megacycles through 10 kilomegacycles.

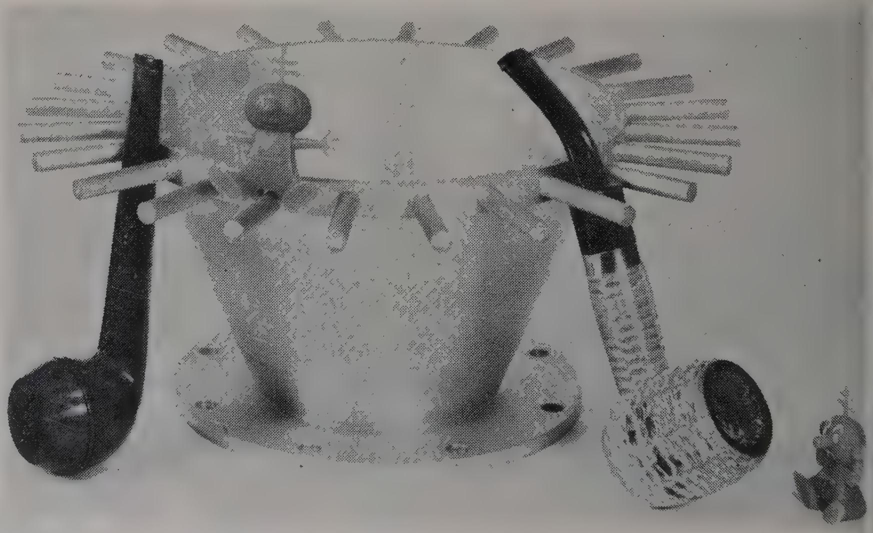
CMD-3048 has an adjusted dielectric constant of three through 10 in steps of one and a volume resistivity above 10^{13} ohm-cm. Fabricated shapes are available from the factory.

Circle Reader Service Card 144

—mwj—

(Continued on page 110)

New Product?



The compensated electromagnetic horns shown on the cover and described on page 84 have another use, according to the author, Mr. James J. Epis. "I never mentioned in my paper," he wrote, "that they also make 'nice' pipe stands."

NEW

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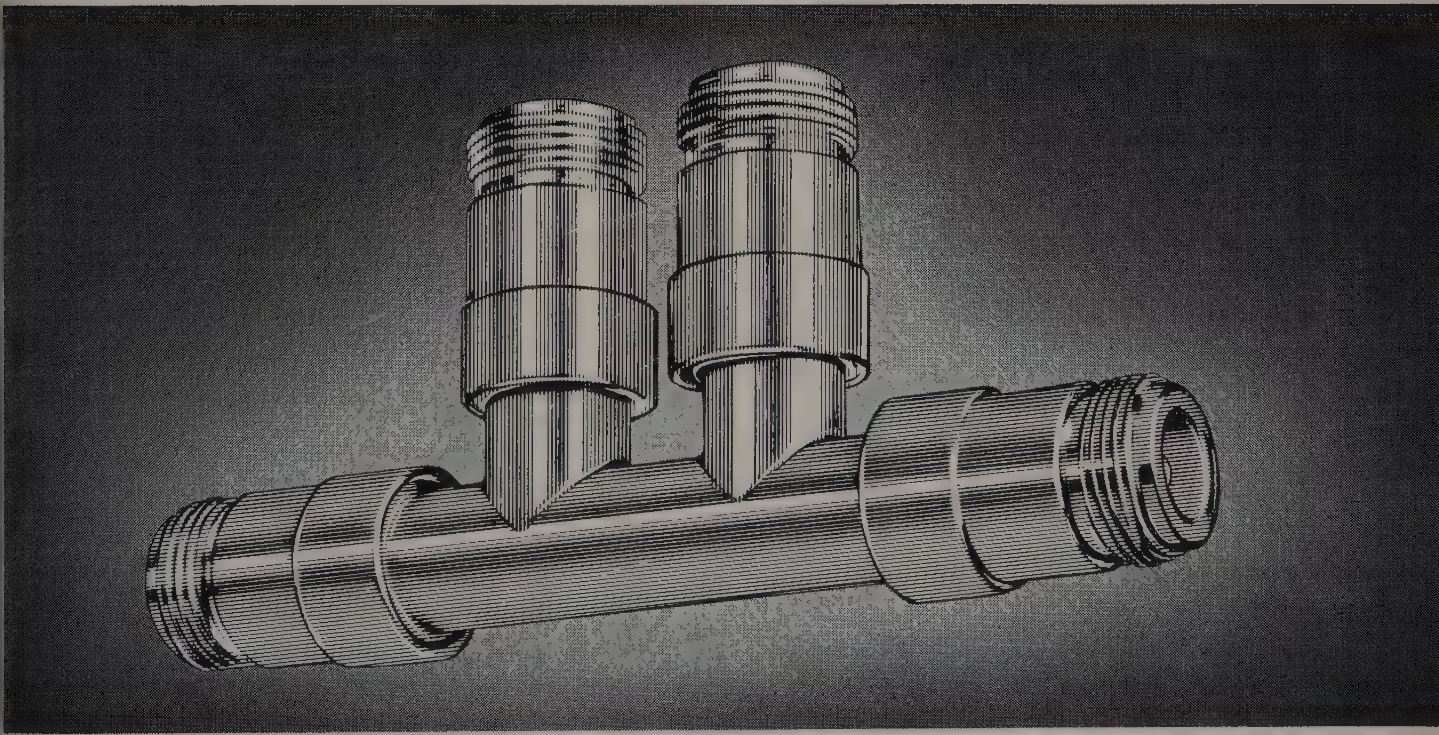
MICROLAB OFFERS THE BROADEST LINE OF DIRECTIONAL COUPLERS AVAILABLE FROM STOCK.

THE CA, CB, CC, CE, CF, CG AND CH SERIES ARE AVAILABLE IN 42 STANDARD FREQUENCY RANGES FROM 200 MC TO 4000 MC WITH N, BNC, TNC AND C SERIES CONNECTORS. THE TUBULAR DESIGN ASSURES A SMALLER PACKAGE WITH LIGHTER WEIGHT FOR USE IN LABORATORY, PRODUCTION TESTING OR MICROWAVE SYSTEMS. MODIFICATION OF THE STANDARD COUPLERS AND/OR CONNECTORS ARE AVAILABLE ON REQUEST. WRITE FOR CATALOG 10A.



MICROLAB

70 West Mt. Pleasant Avenue • Livingston, New Jersey • WYman 2-570

Circle Reader Service Card 63

(*Continued from page 108*)

LIGHT WEIGHT FLOATING DRIFT TUBE KLYSTRON OFFERED

Model LKC-5 Klystron, a single cavity oscillator featuring high efficiency, light weight, and no magnetic field requirements, is offered by Lewis and Kaufman Electronics Corp., Los Gatos, Cal.

Employment of a "one way" electron beam eliminates hysteresis problems common to reflex type Klystrons. As the electron beam never returns to the cathode, mechanical and thermal damage is eliminated, greatly increasing tube life.

Readily scaled for operation at frequencies from 800 to 13,000 megacycles depending on customer requirements — these tubes require only one adjustment to fix oscillation frequency.

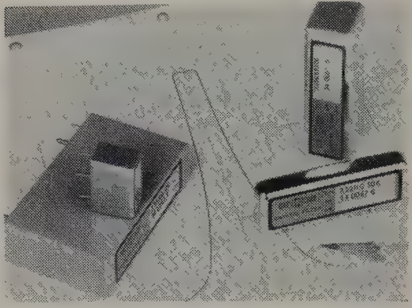
With a maximum height of 1.70 inches, and net weight of 5 ounces the LKC-5 performs in any operating position. The Model LKC-5 Klystron is well adapted to telemetering, doppler radar and navigation, relay links, and other microwave communication system applications.

Delivery approximately five weeks after receipt of order.

Circle Reader Service Card 108

—*mwj*—

COLLINS RADIO ANNOUNCES NEW CRYSTAL FILTER LINE



Collins Radio Co. has announced a new line of Crystal Filters for a broad range of applications in single sideband, telemetering, missile guidance, radar and navigation equipment and other communication and electronics uses. The new components are being produced by Collins Radio Company's Western Division, Newport Beach, Cal.

Crystal Filters over the 10 kc to 30 Mc frequency range are now being produced in quantities. One of the new units is a five Mc filter in a thumb-size 3/8 cubic inch case, less than half the package size previously available. These new Crystal Filters complement the established line of Collins Mechanical Filters, providing highly selective, compact bandpass filters for the 10 kc to 30 Mc frequency range.

Supplementing the line of standard filters, an Application Engineering and Prototype Design staff is ready to evaluate special filter requirements and to provide engineering samples.

Circle Reader Service Card 109

—*mwj*—

DIELECTRIC PRODUCTS OFFERS SMITH CHART IMPEDANCE PLOTTER

Dielectric Products Engineering Co. Raymond, Maine, has released details on its new Smith Chart Impedance Plotter.

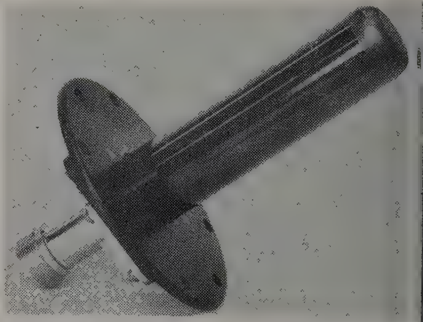
Providing instantaneous display of impedance as a continuous function of frequency in the 10 to 3000 Mc/s range, the Smith Chart Plotter is designed to supply peak accuracy with new speed and simplicity.

The Smith Chart Plotter gives VSWR uncertainty as low as 1.01. The oscilloscope trace may be directly photographed for permanent recording, or an X-Y chart recorder may be used. The Dielectric Smith Chart Couplers, available in five models for ranges from 10 to 3000 Mc/s, employ two push-pull outputs for horizontal and vertical oscilloscope channels. Impedances at the coupler terminal may be read directly on the oscilloscope, and by rotating the faceplate, readings may be taken at all points along the output transmission line.

Circle Reader Service Card 110

—*mwj*—

VERTICALLY POLARIZED S-BAND ANTENNA ANNOUNCED



The Adams-Russell Co., Inc., Cambridge, Mass., announces the development of vertically polarized S-Band antenna, Model 3001. This antenna has been designed for use in transmitting from a aircraft or as a ground beacon when used over a ground screen.

The electrical characteristics are vertical polarization; 500 watts CW power rating; 1.5 max. VSWR: 2400 - 3600 Mc band width; 10 db gain in elevation relative to isotropic and omnidirectional pattern in azimuth. The unit is completely sealed and contains an internal silicagel reservoir. Limited quantities available from stock and production quantities available within forty-five days.

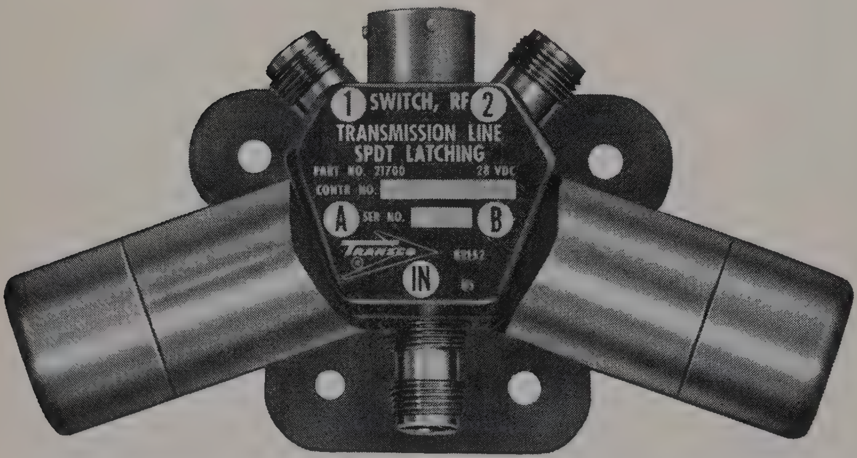
Circle Reader Service Card 111

(*Continued on page 112*)

—*mwj*—

Circle Reader Service Card 65

NO
HOLDING
POWER
NEEDED



NEW TRANSCO COAXIAL LATCHING SWITCH

No holding power needed with this new Transco switch. Solenoids stay cool, ending heat worries. Compact unit operates to 11 KMC and meets military specifications. Typical specifications at 7 KMC: IMPEDANCE 50 ohms; VSWR 1.3; INSERTION LOSS 0.3 db; CROSSTALK 40 db; WEIGHT 8.7 oz. Please write Transco Products, Incorporated, 12210 Nebraska Avenue, Los Angeles 25, California for complete information.

TRANSCO

COAXIAL SWITCHES • WAVEGUIDE SWITCHES • ANTENNAS • MICROWAVE COMPONENTS VALVES • ACTUATORS

Circle Reader Service Card 64

Here's Something NEW In 28-Foot Parabolic Reflectors...

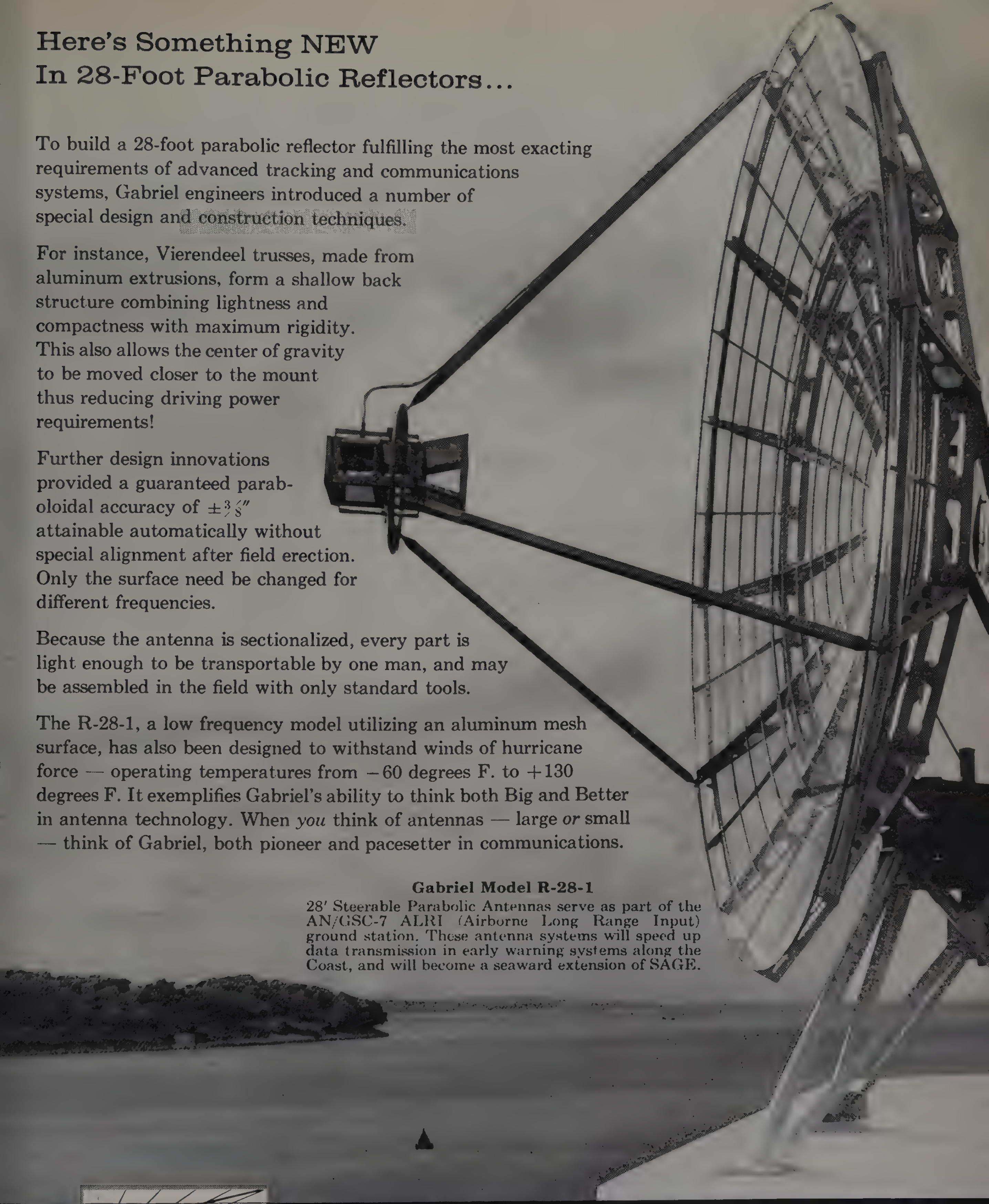
To build a 28-foot parabolic reflector fulfilling the most exacting requirements of advanced tracking and communications systems, Gabriel engineers introduced a number of special design and construction techniques.

For instance, Vierendeel trusses, made from aluminum extrusions, form a shallow back structure combining lightness and compactness with maximum rigidity. This also allows the center of gravity to be moved closer to the mount thus reducing driving power requirements!

Further design innovations provided a guaranteed paraboloidal accuracy of ±$\frac{3}{8}$″ attainable automatically without special alignment after field erection. Only the surface need be changed for different frequencies.

Because the antenna is sectionalized, every part is light enough to be transportable by one man, and may be assembled in the field with only standard tools.

The R-28-1, a low frequency model utilizing an aluminum mesh surface, has also been designed to withstand winds of hurricane force — operating temperatures from −60 degrees F. to +130 degrees F. It exemplifies Gabriel's ability to think both Big and Better in antenna technology. When *you* think of antennas — large *or* small — think of Gabriel, both pioneer and pacesetter in communications.



Gabriel Model R-28-1

28′ Steerable Parabolic Antennas serve as part of the AN/GSC-7 ALRI (Airborne Long Range Input) ground station. These antenna systems will speed up data transmission in early warning systems along the Coast, and will become a seaward extension of SAGE.

PIONEERS IN ANTRONICS

Gabriel electronics DIVISION OF THE GABRIEL CO., MILLIS, MASS.

AIRPORT SURVEILLANCE RADAR ANTENNAS

ROTARY JOINTS

POINT TO POINT COMMUNICATION ANTENNAS

FEEDS AND HORNS

DRONE & DRONE CONTROL ANTENNAS

RESEARCH & DEVELOPMENT

COMPARE...
and you'll use
SPERRY *Microline*®
29A1 SWR Indicator

SWR INDICATOR MODEL 29A1
SPERRY MICROWAVE ELECTRONICS COMPANY
SPERRY Microline

IMMEDIATE DELIVERY **$200**

Many features designed into the 29A1 are not normally included at such a low price. And it is available for immediate delivery.

Adjustable bandwidth allows maximum sensitivity with freedom from modulator drift errors. Positive protection against bolometer burnout. Expanded scale with automatic gain compensation. Push-to-read bolometer current. Plus 5 db gain supplement always assures accurate upscale meter readings. Designed for ease of operation.

Frequency:	1000 cps ± 1%
Sensitivity:	0.1 uv for full scale deflection
Noise Level:	Less than 0.03 uv at min. bandwidth
Bandwidth:	Wide Band: 300-5000 cps Narrow Band: continuously adjustable 30-150 cps
Range:	70 db adjustable in 5 db steps accurate to ± .1 db per step
Recorder Output:	0 to 1 ma, 1500 ohms, one side grounded
Dimensions:	Approx. 8″ x 11″ x 12″

SPERRY

SPERRY MICROWAVE ELECTRONICS COMPANY, CLEARWATER, FLORIDA
DIVISION OF SPERRY RAND CORPORATION **Microline Instruments** • Radar Test Sets • Systems Instrumentation • Solid State Devices and Materials • Microwave Components and Antennas

Circle Reader Service Card 66

New Products

(*Continued from page 110*)

GUIDE DEVELOPS X-BAND MICROWAVE SWITCH

GUIDE MFG. CO.

Long life, reliability and a high degree of isolation under extreme conditions are featured in a new X-band microwave switch developed by Guide Manufacturing Co., Sun Valley, Cal., for use in airborne and ground support systems.

The new switch has been designated Series 1900.

The key advantages of the Guide switch lie in its ability to handle high power with positive reliability through a million-operation lifetime. Another feature is the high degree of isolation possible — greater than 50 db under extreme mismatch conditions.

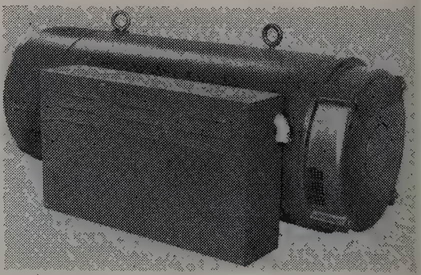
In rugged laboratory tests, the switch has provided isolation of greater than 60 db, with the arms terminated. Adjustment of a movable short for the worst possible mismatch yields a minimum isolation of 50 db.

Circle Reader Service Card 112

— *mwj* —

MOTOR-GENERATOR SETS USED FOR MICROWAVE RELAY STATIONS

The Western Electric Co., New York, N. Y., is being supplied with Allis-Chalmers five kw motor-generator sets for cross-country remote microwave relay stations to be operated by the Bell Telephone System.



Utilizing compact two-bearing construction, the motor-generator sets consist of a Synduction motor, a dc motor, a single phase generator and exciter within a common yoke. All rotating parts are mounted on a single shaft supported by a bearing at each end and the regulator is located in a cabinet on the side of the set.

A brushless generator operates in conjunction with a static type regulator to supply a 230-volt output at ±one per cent. Power for operating the regulator is taken from the generator output.

During normal operation the Synduction motor drives the generator with input power taken from commercial sources and the dc motor on standby. Fields and brushes are energized from a 120-145- volt battery with the brushes removed from the commutator by mechanically linking them to solenoids connected to the same source supplying the Synduction motor.

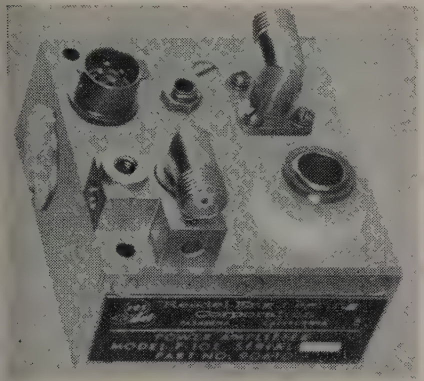
Circle Reader Service Card 113

—*mwj*—

RESDEL ADDS TO MINIATURE AMPLIFIER LINE

Resdel Engineering Corp., Pasadena, Cal., announces the latest addition to its line of miniature amplifiers for aerospace applications and G.S.E.

The company states this series of miniature amplifiers is ruggedly designed for high efficiency and reliability under the severe environments of deep space operations. Circuit design, choice of the tube type and operating parameters are optimized for maximum efficiency and offer the designer a choice of combination of power, function and frequency range operation.



Each model can be ordered in six output frequency ranges from 215 - 1100 Mc. Heater supply is 6.3 volts @ .225 ampere for all units. Refer to tube manufacturer for recommendations for higher frequency operation.

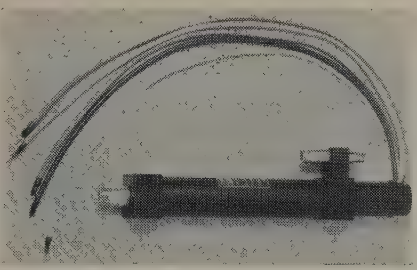
Circle Reader Service Card 114

—*mwj*—

LITTON INTRODUCES L-3472 TRAVELING WAVE TUBE

An L-3472 traveling wave tube, introduced by the Electron Tube Division of Litton Industries, Beverly Hills, Cal., offers engineers a tube high in CW power (10 watts minimum), wide in bandwidth and small in size and weight.

The new, compact TWT, which operates in the frequency range of 7000 to 11,000 megacycles, also features higher linear power. Special helix design and fabrication techniques have raised the saturation gain to within three db of small signal gain. Small signal gain is 36 db minimum. In applications where the power output must be a linear function of power input, this Litton technique provides at least three db greater usable power output than standard designs.



The input and output circuits are coaxial, having minimum frequency dependence. Usable bandwidth is limited only by the electronic bandwidth of the beam and circuit combination.

Circle Reader Service Card 115

—*mwj*—

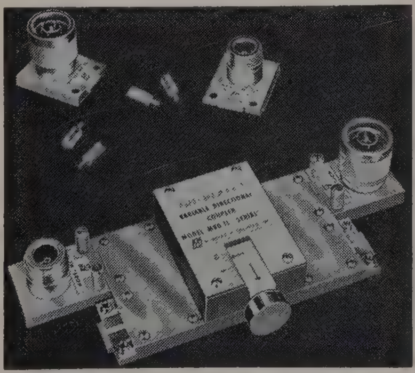
SANDERS INTRODUCES VARIABLE COUPLER LINE

Sanders Associates, Inc., Nashua, N. H., has introduced a line of precision-made Tri-Plate variable directional couplers for strip transmission line circuits with coupling as tight as two db's.

The devices, which have broadband applications, can perform as adjustable directional couplers, power dividers or variable attenuators with controllable power handling capacity and wide attenuation range.

The new series of nine models of Tri-Plate variable couplers are available from stock in three overlapping frequency ranges, each covering one or more octives between UHF and upper S-band. Within each frequency band, three models are available with coupling at three, eight, or 20 db's. Tri-Plate variable directional couplers are also laboratory tools and are furnished to mate with the complete line of over 300 Tri-Plate modules or with transitions for use with coax.

As a single unit, the Tri-Plate Variable Directional Couplers provide equal three db outputs, or any other designated power ratio. Multiple units can be cascaded to provide adjustable power dividers with four, eight, 16, or more adjustable (non-lossy) outputs in any ratio or power.



Circle Reader Service Card 116

—*mwj*—

(*Continued on page 114*)

SPERRY *Microline*®

highly accurate
IMPEDANCE INSTRUMENTS

UNIVERSAL CARRIAGE 21A1

This carriage is machined to a high degree of accuracy and carefully designed for long life and low wear of parts. Extreme rigidity and factory adjustment assure precision travel of probe within waveguide walls enabling the most accurate of SWR measurement.

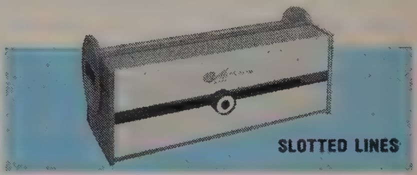
SLOTTED SECTIONS
(for use in Universal Carriage 21A1 above)

These sections fit precisely into the Microline 21A1 Universal Carriage assuring perfect positioning with respect to travel of the probe tip. Each slot is tapered at both ends to reduce secondary slot effects.

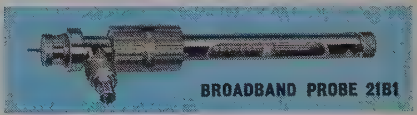
SPECIFICATIONS

Model	Frequency Range Kmc	Price
21A1 (Universal Carriage)	3.95-18.0	$160
21C1	3.95-5.85	110
21G1	5.2-8.2	110
21H1	7.05-10.0	110
21X1	8.2-12.4	90
21U1	12.4-18.0	110

Residual VSWR (Max), 1.01



These are precision built units for applications in S and L bands, machined and manufactured to the same fine tolerances as the 21A1 Universal Carriage. Precision slotted waveguide casting is integral with the carriage.



For use with all of the above units we recommend the Microline 21B1 Broadband Tunable Probe. This probe is outstanding because of its unique dual action repeatable tuning adjustments, and its complete freedom from any type of erratic operation.

SPERRY

SPERRY MICROWAVE ELECTRONICS COMPANY,
Clearwater, Fla., Division of Sperry Rand Corp.

Circle Reader Service Card 67

TRAK Type
9127-SL(CW),
tunable 2.15—
2.45 KMc

NEW–TRAK OSCILLATOR CAVITY FOR CW SERVICE!

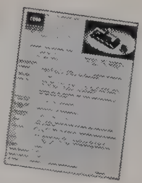
This MINIATURE TRAK Type 9127-SL(CW) Microwave Cavity is ideal as a local oscillator or low power transmitter in the new 2.2—2.3 KMc telemetry band. With a power output in excess of 100 mw, it is also suitable for use as a parametric pump, or the energy source for harmonic generators.

Specifications are:

Frequency	Tunable 2.15—2.45 KMc
CW Power Out	Greater than 50 mw over entire tuning range Greater than 100 mw over 2.2—2.4 KMc range
Power Input	150 VDC at 10 ma and 6.5 V at 240 ma
Temperature Stability	Less than 1 Mc drift with a temperature variation of 80°C. Operable from —70° to +120°C.
Size	1" diameter by 4¾" long
Weight	7 ounces

TRAK MICROWAVE has miniature CW Oscillators with output power of 10 mw to 2 watts at frequencies between 800 and 7000 Mc. Also, Oscillators engineered to your specifications!

Write today for **new**
Catalog 61A, full
of oscillators for CW,
grid pulse and
plate pulse service.



Microwave Oscillator Engineers Wanted

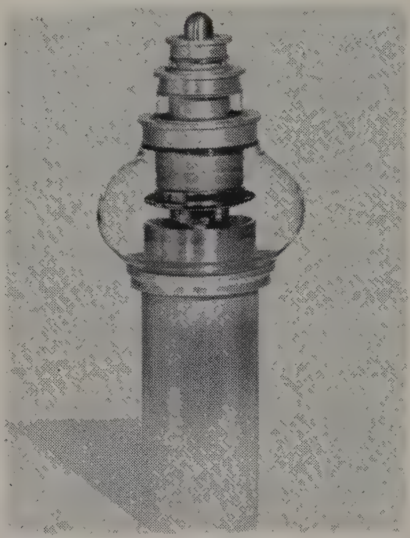
TRAK Microwave

TRAK MICROWAVE CORPORATION
Subsidiary of
TRAK Electronics Company
5006 N. Coolidge Avenue
Tampa 3, Florida
REdwood 6-6422

Circle Reader Service Card 68

(*Continued from page 113*)

MACHLETT DESIGNS HIGH-MU TRIODE



A high-mu triode, designed primarily for radar, communications and similar systems, has been announced by The Machlett Laboratories, Inc., Springdale, Conn.

Operating as a switch tube in hard-pulse modulators, the ML-8038 can deliver a pulse power output of 10 - 20 megawatts. The tube features rugged concentric construction, and when operating in oil or an equivalent dielectric liquid, it has a maximum plate voltage rating of 125 kv.

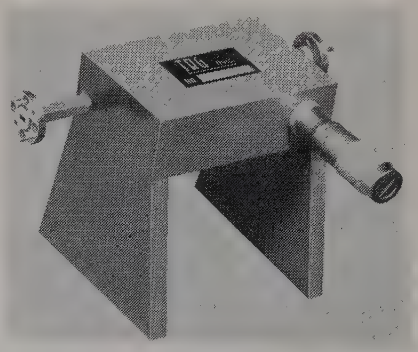
The cathode is a sturdy, thoriated-tungsten filament, with a self-supporting design that eliminates stress. The tube's anode is capable of dissipating 5 kw when cooled by free convection in oil.

Circle Reader Service Card 117

—mwj—

TRG INTRODUCES TUNABLE FERRITE ISOLATOR

Technical Research Group, Inc., Somerville, Mass., announces the availability of the Ferimat, a tunable ferrite isolator for A, V, and E bands. An F-band is currently under development.



The Ferimat operates over the full waveguide frequency range, doing the work of a half dozen or more fixed tuned isolators. Typical performance ratings for A, V, and E bands are as follows: VSWR — 1.25 max.; isolation — 20 db minimum; loss — 1.5 db max.

Typical applications include laboratory test bench equipment, experimental microwave circuitry, signal generators and broadband counter measure systems.

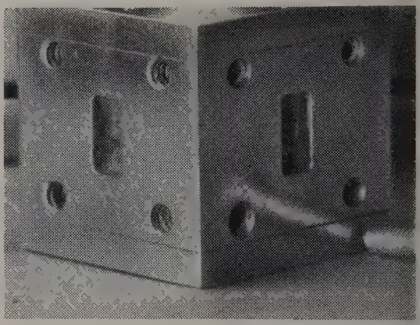
The new Ferimat is one of a complete line of millimeter wave components of all types available from TRG, covering the entire 26.5 kMc region.

Circle Reader Service Card 118

—mwj—

WESTINGHOUSE DEVELOPS DUAL-MODE DISCRIMINATOR CAVITY

A dual-mode transmission-type discriminator cavity has been developed by the Westinghouse Electric Corp., Pittsburgh, Pa., as a rugged, frequency stabilizing device for such applications as parametric amplifier pumps, navigation systems, and beacon radars requiring a highly stable frequency source.



A cavity already in production — the WX 4334 — is designed to operate at 35,000 megacycles, but designs for other fixed frequencies are available. To minimize the influence of change in ambient temperature on frequency drift, the cavity is vacuum sealed and employs invar construction. A change in resonant frequency of plus or minus eight megacycles is typical for a temperature change of 25 to 100 degrees Centigrade.

Typical operating characteristics include ambient temperature range of minus 55 to plus 100 degrees C, a loaded Q for each output of 3000, and a frequency difference between outputs of 10 megacycles. Insertion loss input to each output is ten decibels maximum, and insertion loss difference between outputs is one decibel maximum.

Circle Reader Service Card 119

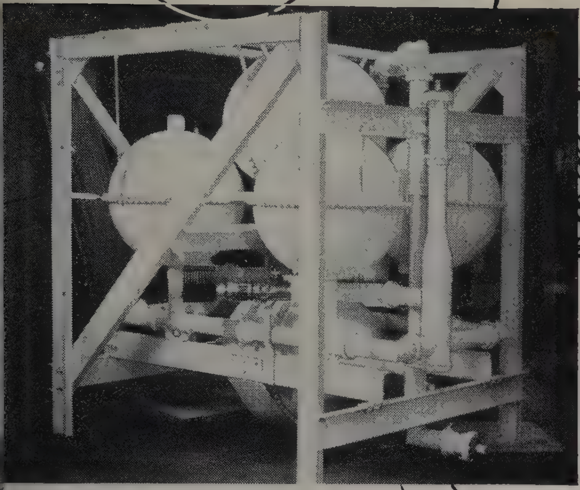
—mwj—

MINIATURIZED MICROWAVE TUNNEL DIODES ANNOUNCED

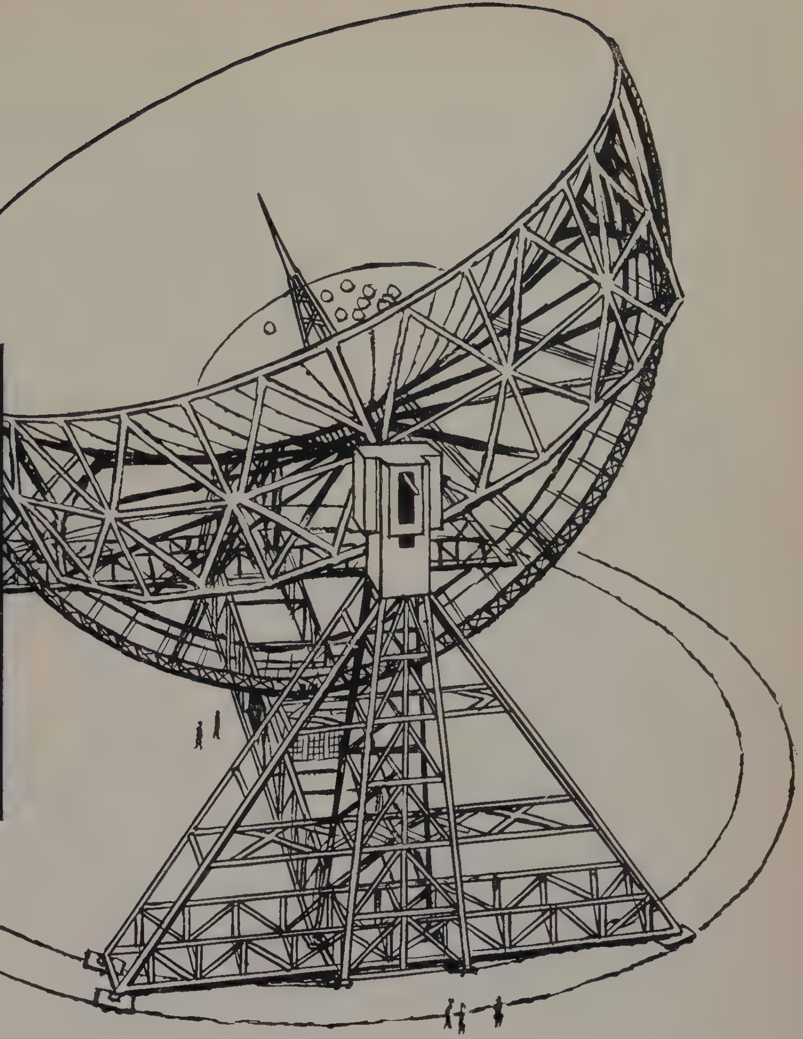
Sylvania Electric Products Inc. and General Telephone & Electronics Laboratories Inc. have announced jointly the

(*Continued on page 116*)

ANOTHER MEASURE OF DIELECTRIC'S CAPABILITY



THIS UHF DIPLEXER NETWORK was built by **DIELECTRIC** Products Engineering Company, Inc., under contract from Space Technology Laboratories, Inc. It is now installed in the tower of the single giant antenna of "SpaN Net's" Jodrell Bank radio telescope at Manchester, England. Its function is



solating simultaneous signals to and from deep-space payloads

Commanding and monitoring space vehicles is the responsibility of "SpaN Net" . . . a global network of radio telescopes set up and operated by Space Technology Laboratories for U.S.A.F.

To fulfill its mission, "SpaN Net" had to meet challenges far beyond the state of the communications art. Never before had powerful command signals and faint telemetered deep-space data been simultaneously handled by a single antenna. How could transmit and receive channels with a differential of more than 200 decibels be isolated? Conventional diplexer technology was not the answer.

Teamwork solved the isolation problem! "SpaN Net" assigned the task to Space Technology Laboratories, Inc., who added DIELECTRIC of Maine to its research, development and production team. Result? An ultra-high-frequency diplexer network that allows the Jodrell Bank radio telescope's single antenna to transmit 20 kw commands and receive 0.002 microvolt signals . . . simultaneously.

This contribution to SpaN Net's break-through is typical of product advances by DIELECTRIC. If you have similar problems in communications . . . from design to delivery . . . it pays to contact DIELECTRIC. Capabilities, facilities and accomplishments are described in our brochure. Write for it today.

"Visit our exhibit at AFCEA, Booths 95-96, Sheraton Park Hotel."

Other areas of **DIELECTRIC** capability in coaxial, waveguide and open wire techniques . . .

TRANSMISSION LINE & COMPONENTS • NETWORKS • SWITCHES • ANTENNAS & FEEDS
TEST EQUIPMENT • R&D ENGINEERING

dial DIELECTRIC for solutions to communications problems.

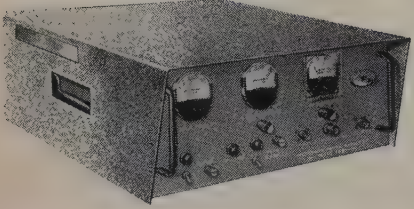
DIELECTRIC PRODUCTS ENGINEERING CO., INC.

RAYMOND, MAINE

Circle Reader Service Card 69

NEW!

MICROWAVE POWER AMPLIFIERS AT NEW LOW PRICES



2 kmc to 20 kmc

ONE WATT OUTPUT OVER MOST OF RANGE IN ONLY 2 TWT AMPLIFIERS

MODEL T601 — 2 to 15 Kmc
$4,995.00

MODEL T602 — 10 to 20 Kmc
$5,690.00

• FEATURES •

- Rugged construction
- Regulated and metered power supplies
- Provision for modulation
- Adjustable gain control

TYPICAL APPLICATIONS INCLUDE:

- Conversion of low level signal generators to high power sources • Efficient harmonic generator • Antenna pattern measurement source • Converts to high power oscillator with appropriate adapter
- Accessory equipment soon available

AEL

AMER. ELECT. LABS., INC.
121 N. 7TH ST., PHILADELPHIA 6, PA.
In Canada contact: Conway Electronic Enterprises Regd. Toronto, Canada

New Products

(*Continued from page 114*)

development of a miniaturized tunnel diode, which oscillates at frequencies of 10,000 megacycles and above. This is three times the range of previously announced tunnel diodes.

Dr. Herbert Trotter, Jr., President of GT&E Labs, Bayside, N. Y., which developed the new device, said its increased capabilities will further the quest for practical applications of tunnel diodes, particularly in the microwave area.

Designated D-4168-D, the 10 kMc, P-type germanium tunnel diode has peak currents of approximately 3.5 ma and minimum peaks to valley ratios of 5:1. Peak current ranges from four to 50 ma have also been developed.

Ernest H. Ulm, general marketing manager of Sylvania's Semiconductor Division, Woburn, Mass., which will produce and market the new device, said production quantities are presently available.

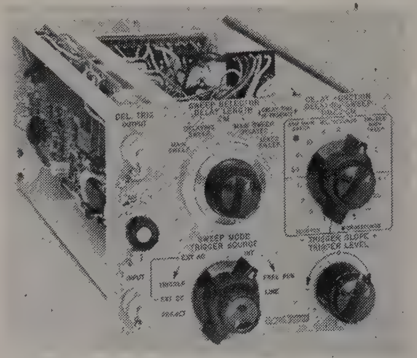
Circle Reader Service Card 120

—*mwj*—

PLUG-INS INCREASE OSCILLOSCOPE VERSATILITY

Two horizontal plug-in units which increase the versatility of Hewlett-Packard's Model 160B and 170A oscilloscopes are now available from Hewlett-Packard Co., Palo Alto, Cal.

The Model 160B is a 15 Mc oscilloscope, while the 170A is a 30 Mc unit. Both are built to exacting military specifications. The new time-axis plug-ins are the Model 166C Display Scanner and the Model 166D Sweep Delay Generator.



The Model 166C Display Scanner provides an output to duplicate, on an X-Y recorder, any repetitive waveform appearing on the CRT trace. The permanent, large-scale record obtained provides higher resolution than either the CRT display or a photograph. The trace can be viewed on the CRT while an X-Y recording is being made.

Model 166C converts high speed signals to slower signals having the same waveshape. The unit's scanning speed is arranged to keep the Y output within the bandwidth of conventional recorders.

Circle Reader Service Card 121

—*mwj*—

LOW-NOISE TWT POWER SUPPLY AVAILABLE

Watkins-Johnson Co., Palo Alto, Cal., has developed a rugged field-reliable low-noise TWT power supply designed to furnish all necessary power to operate WJ-211 and WJ-212 S- and L-band ultra low-noise traveling-wave tubes, as well as their packaged counterparts, the WJ-111 and WJ-112.

The WJ-180 operates off a 105 to 125 volt, 48 to 420 cps, single-phase power source and uses solid-state components throughout, thereby maximizing its efficiency and ensuring long maintenance-free operation. The design provides for stabilization against line voltage variation and ambient temperature change. All components used are selected and applied with adequate derating factors.

Watkins-Johnson has pointed out that satisfactory operation by relatively unskilled personnel is assured, since operating adjustments are unnecessary and only two front panel controls are used.

Circle Reader Service Card 122

—*mwj*—

TWO "CERMOLOX" TUBES INTRODUCED BY RCA FOR SATELLITE EQUIPMENT

Two new, very small conduction-cooled ultra-high-frequency Cermolox tubes, designed for use in missiles and satellites as well as in mobile and fixed communications equipment, were introduced by the RCA Electron Tube Division, RCA, New York, N. Y.

C. E. Burnett, Division Vice President, Industrial Tube Products Department, said the new tubes, RCA-7801 and RCA-7870, were developed for a variety of applications in which small size and compactness of equipment are of utmost importance.

Both tubes have an overall length of less than 1 1/4 inches, a maximum diameter of nearly 3/4 of an inch, and weigh about half an ounce.

At 3000 Mc these new tubes can provide 3.2 watts of CW power output with one watt of driver power output or they can provide a gain of nine db with 50 milliwatts of driver power output.

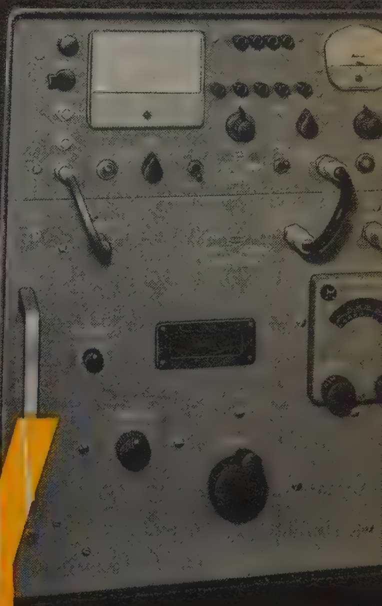
Circle Reader Service Card 123

—*mwj*—

(*Continued on page 119*)

NEW CALIBRATED FIELD INTENSITY RECEIVER

POLARAD
PROVEN RELIABILITY



COMBINES SIGNAL GENERATOR AND RECEIVER IN SINGLE UNIT

1,000 to 10,000 mc*

*Two compatible tuning units under development will extend frequency to 20 kmc.

Now, in a single unit, the new Polarad Model FIM indicates the absolute power level of a radiated or conducted input signal by comparing it against an internally generated signal.

- Model FIM accurately measures frequency and absolute power level of microwave energy.
- Only microwave Field Intensity Receiver with self-contained signal generator which calibrates entire system under test at any level.
- First single microwave test system to determine r-f interference and susceptibility to interference.
- Front-panel meter indicates average, peak, slide-back peak or quasi-peak value of r-f signals. Outputs for video, audio and recorder.
- Four interchangeable tuning heads cover 1,000 to 10,000 mc.
- Direct-indicating peak VTVM for ease of frequency location of impulse noise.
- Single UNI-DIAL tuning control tunes both the receiver and signal generator.
- Calibrated antenna system includes an omnidirectional broad band antenna and a separate directional antenna to match each tuning unit.

MAIL THIS CARD for specifications. Ask your nearest Polarad representative (in the Yellow Pages) for a copy of "Notes On Microwave Measurements."

12345678

POLARAD ELECTRONICS CORPORATION:

Please send me information and specifications on:

☐ Model FIM Calibrated Microwave Field Intensity Meter

My application is

☐ Model R Receiver (see reverse side of this page)

My application is

Name

Title Dept.

Company

Address

City Zone State

POLARAD
ELECTRONICS CORPORATION

FREE LIFETIME
SERVICE

43-20 34th Street,
Long Island City 1, N. Y.

MICROWAVE RECEIVER

Model R • 400 to 84,200 mc

A MULTI-PURPOSE PRECISION TEST INSTRUMENT

DETECTS AND MEASURES:

- Antenna patterns
- Field intensity
- R-F power
- R-F noise figure
- Leakage and interference
- Filter characteristics
- Bandwidth of microwave cavities
- Attenuation
- Insertion gain and loss
- Relative power differences between fundamental signal and harmonics

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LARAD ELECTRONICS CORP.
20 34th St., Long Island City 1, N.Y.

Now — one basic instrument serves for general communications as well as for detection and complete quantitative analysis of microwave energy.

Polarad Model R Receiver accepts all microwave signals: AM, FM, CW, MCW and pulse. Power and frequency are read directly on front panel indicators.

It permits all standard forms of signal monitoring: special output jacks for audio and video; trigger output to reproduce pulse width and repetition rate; recorder output to transcribe signals through commercial recording equipment.

Model R is simple to operate, extremely sensitive, highly accurate, and is designed for quick, easy inspection and servicing. It provides AFC, AGC, and continuous UNI-DIAL tuning. Nine interchangeable tuning units cover the entire frequency range. A tenth tuning unit is available for antenna pattern measurements from 2000 to 75,000 mc.

MAIL THIS CARD for specifications. Ask your nearest Polarad representative (in the Yellow Pages) for a copy of "Notes on Microwave Measurements"

POLARAD
ELECTRONICS
CORPORATION

FREE LIFETIME
SERVICE

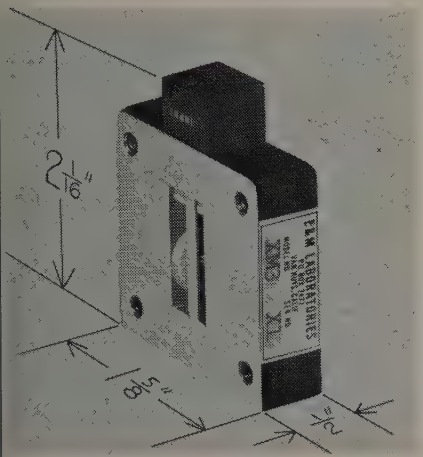
Representatives in principal cities

(*Continued from page 116*)

X-BAND ISOLATOR LINE EXPANDED

E&M Laboratories, Van Nuys, Cal., has expanded its line of X-band 1/2 inch isolators with the introduction of Model XM3 covering the frequency spectrum from 9250 to 9500 Mc/s.

This isolator provides a minimum isolation of 15 db, with a maximum insertion loss of 0.5 db and maximum VSWR of 1.2, over the temperature range of −40°C to +85°C.



Model XM3 sells for $200.00 in single quantities. The center frequency insertion loss and isolation may be modified to meet specific customer requirements.

Circle Reader Service Card 124

—*mwj*—

GERMANIUM TUNNEL DIODES FEATURE LOW NOISE CONSTANTS

Germanium Tunnel Diodes, Types MS222, 223, 224 and MS242, from Micro State Electronics Corp., Murray Hill, N. J., are designed for UHF and microwave amplier and oscillator applications in communication systems.

These diodes feature low noise constants as well as typical cutoff frequencies of 3.5 kMc. Germanium tunnel diodes with cutoff frequencies to six kMc will also be available from Micro State in the near future.

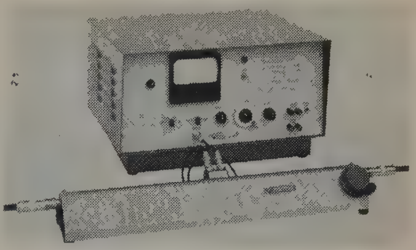
These diodes are packaged in a "pillbox" configuration .120 inch diameter and .050 inch high which minimizes parasitic inductance and capacitance. All types exhibit superior noise constant characteristics. The very low noise of these diodes makes them useful in low noise tunnel diode amplifiers. A curve of the V-1 characteristic accompanies each diode.

Both design and specifications of these new Micro State germanium tunnel diodes are oriented toward communications applications. The result is the semiconductor industry's first microwave communication-oriented tunnel diode.

Circle Reader Service Card 125

—*mwj*—

WILTRON ANNOUNCES MICROWAVE PHASE METER



Wiltron Co., Palo Alto, Cal., announces a Direct Reading Microwave Phase Meter for checking the relative phase between two signals in the 300 Mc to 4000 Mc frequency range.

This laboratory instrument measures phase on a meter with 0.1° resolution at the microwave frequency. The principle of operation is that of square law detector response in a standing wave pattern, the standing wave pattern being the resultant of the combination of the two signals whose relative phase is being measured.

The accuracy and sensitivity of measurement permits phase angles to be resolved to .1°. The meter also features a better than 10 to 1 frequency coverage and the ability to handle signals with unequal amplitudes.

The phase meter can be adapted for automatic swept frequency phase measurement with recorder output.

Circle Reader Service Card 126

—*mwj*—

(*Continued on page 120*)

ALL SIZES
M S FLANGES
IN STOCK

THE FINEST QUALITY BRASS AND ALUMINUM STANDARD WAVEGUIDE FLANGES in stock at Formcraft—all precision made to military standards. For rigid and flexible waveguides.

Special flanges to your specifications. Send sketch or blueprint for a quotation.

SEND FOR NEW BROCHURE #14B DESCRIBING AND ILLUSTRATING ALL THE STOCK FLANGES

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Circle Reader Service Card 71

WAVEGUIDE SPEARS
results in VSWR
1.03 max. over
entire guide range

Model	Guide	Tap	Lgth. Base	Price
RDA-10	3x1½	10-32x1.000"	6.25 1.250	$17.00
RDA-11	2x1	8-32x .625"	4.125 .800	15.00
RDA-12	1½x¾	6-32x .500"	3.125 .600	13.00
RDA-13	1¼x⅝	4-40x .500"	2.500 .474	11.00
RDA-14	1x½	4-40x .375"	2.00 .380	11.00
RDA-15	.702x.391	4-40x .312"	1.500 .300	11.00
RDA-16	½x¼	2-56x .250"	1.125 .156	11.00

Immediate Delivery

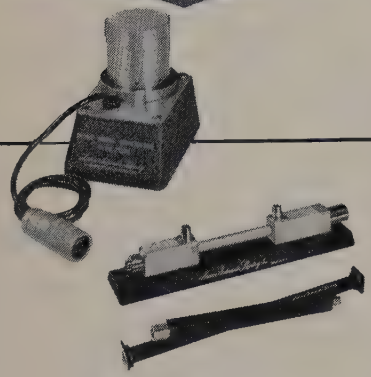
Perpetual, in-the-house Development Programs make "R-D-C" the Microwave Industry's *most versatile* supplier of SPECIAL and STANDARD Coaxial Components:

- ABSORBERS
- ADAPTERS
- ATTENUATORS
- BOLOMETERS
- COUPLERS
- DETECTORS
- FILTERS
- MISMATCHES
- POWER DIVIDERS
- TUNERS
- TERMINATIONS, FIXED
- TERMINATIONS, SLIDING
- SLOTTED LINES
- WAVEMETERS
- SPECIALS

RADAR DESIGN CORPORATION
Pickard Drive — Box 38
Syracuse 11, New York
GLenview 4-4418
TWX SS-437-U

Circle Reader Service Card 72

Noise Generators for All Frequencies from 10 mc to 40 kmc



The AIL Type 70 series of Noise Generators provide the most complete frequency coverage available. Argon gas discharge tubes are used resulting in stable operation and a secondary standard of relative excess noise temperature. All models may be powered by the Type 74 Automatic Noise Figure Indicator or, the the Type 71 Power Supply.

- 8 Waveguide Units: *2.6-40 kmc*
- 1 Coaxial Unit: *0.2-2.6 kmc*
- 2 Diode Units: *10-300 mc*
- Relative Excess Noise Temperature: *15.28 db*
- Accuracy: *±0.25 db: 50 ohm output*

Write for complete description.

AIRBORNE INSTRUMENTS LABORATORY
DEER PARK, LONG ISLAND, NEW YORK
A DIVISION OF CUTLER-HAMMER, INC.

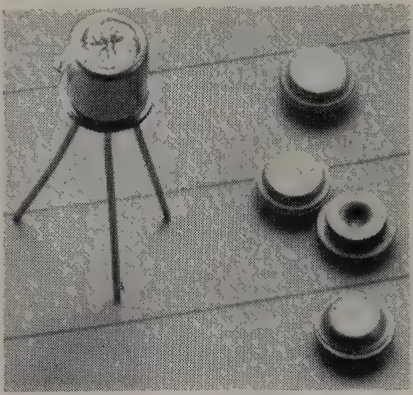
Circle Reader Service Card 73

New Products

(*Continued from page 119*)

GERMANIUM TUNNEL DIODES HOUSED IN NEW MINIATURE PACKAGE

The General Electric Co., Semiconductor Products Dept., Liverpool, N. Y., has announced four microwave frequency germanium tunnel diodes housed in a new miniature package.



The new microwave devices are designed for application in radar, very high frequency amplifiers and oscillators and other "S" band equipment.

They are immediately available in production quantities and are priced from $20.00 to $30.00 each to original equipment manufacturers.

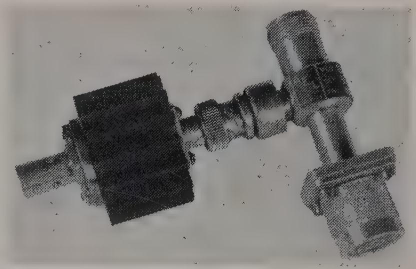
Two of the new germanium tunnel diodes operate at frequencies up to 3500 megacycles and the other two at frequencies up to 4600 megacycles.

Circle Reader Service Card 127

—*mwj*—

CRYSTAL SWITCH DRIVER INTRODUCED BY AEL

AEL, Inc., Philadelphia, Pa., has announced the addition of a crystal switch driver adapter to its line of microwave components.



Designed for use with the AEL line of crystal switches, the driver adapter provides a constant impedance match between the non-linear forward-to-reverse impedance of the switches and the modulation input.

The adapter provides clamping for the forward and reverse modulation to the optimum level (with flat top waveform). The device also protects the crystal switch from burn out due to application of too high a forward voltage.

Supplied with BNC connectors to match the AEL crystal switch, the unit is now available for delivery from stock. The Crystal Switch Driver Adapter is priced at $75.00.

Circle Reader Service Card 128

—*mwj*—

ROCKBAR INTRODUCES VIBRATION GENERATORS

Vibration generators and shaker units for simpler, more accurate analysis of the effects of vibration on components and sub-assemblies are being introduced in the United States by Rockbar Corp., Mamaroneck, N. Y., United States sales representative for Goodmans Industries, Ltd., Wembley, England, manufacturer of the generators.

Used in product design and quality control, the generators simulate vibration effects under varying service conditions. They facilitate controlled vibration tests in the laboratory or shop, eliminating total dependence on field, road, or flight tests.

GOODMANS INDUSTRIES LTD.
3 OHMS

Six models of vibration generators are available, producing peak thrusts ranging from two lbs. to 18,000 lbs. A complete line of ancillary equipment is also available.

Circle Reader Service Card 129

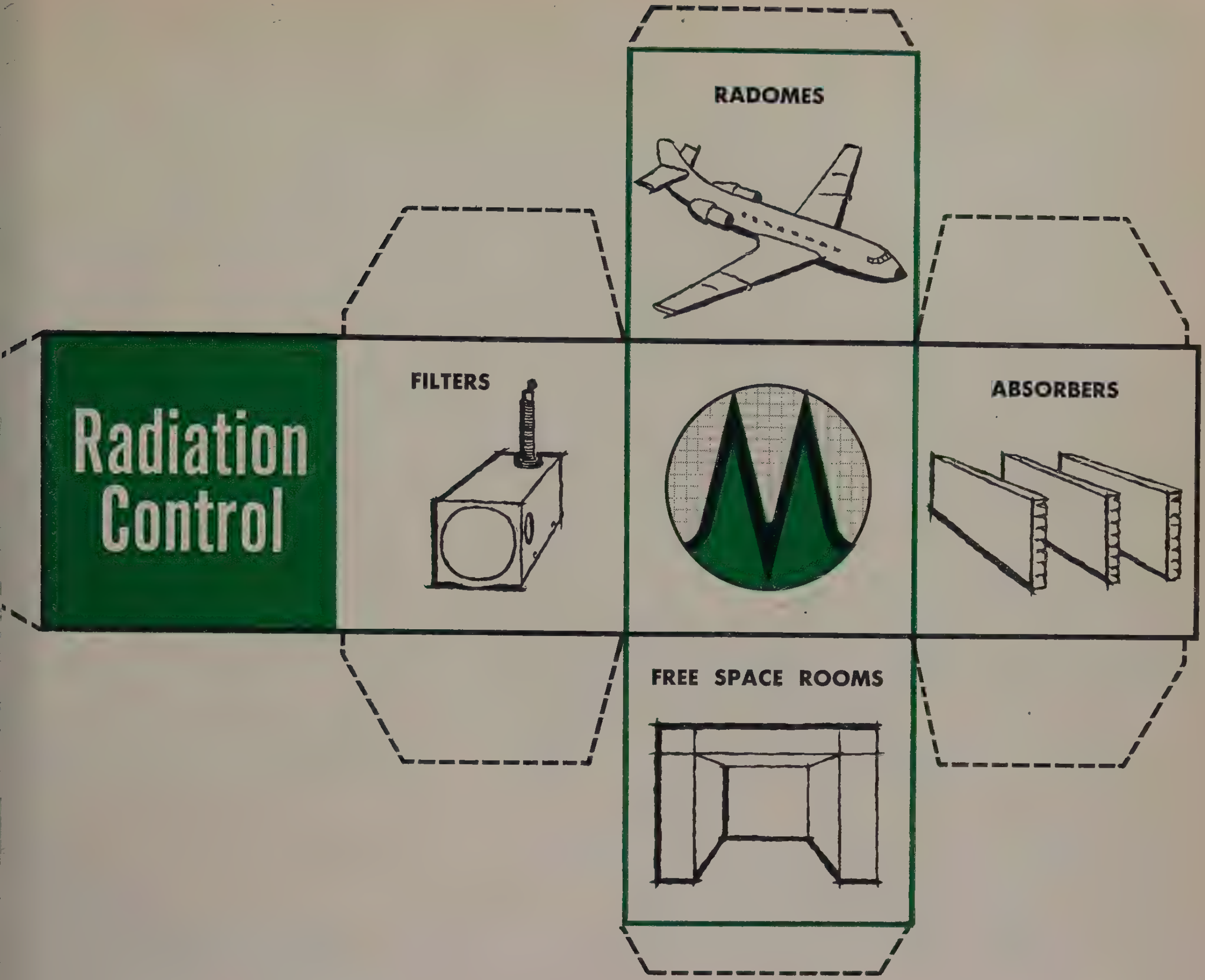
—*mwj*—

FXR HIGH POWER ROTARY JOINTS AVAILABLE

Three new rotary joints, each operating in a specific band over the frequency range one to 9.5 Gc, have recently been made available by FXR's Microwave Division, Woodside, N. Y.

The rotary joint, Model S 60-1, covers

(*Continued on page 122*)



Only McMILLAN Offers this Complete Package for Radiation Control!

. . . . . Whatever your application — for ground support systems, for airborne radar, or for combinations of both — the keynote in radiation control is *compatibility*. Radomes, absorbers, "free space" rooms, R. F. filtering devices — all are instrumental in the control of radiation. The compatibility of these items is vital to proper functioning of the antenna system.

Only McMillan offers you a truly extensive background of engineering in the design, development and manufacture of *all four* of these products. McMillan innovations in radomes, absorbers and special filtering devices remain firsts in their fields. Pre-design consultation is another feature of McMillan engineering service. That's why users of McMillan products form a veritable "Who's Who" in the field of electronics.

Isn't it logical that you, too, can best obtain complete compatibility of the radiation control elements you require by specifying the manufacturer who offers the complete package.

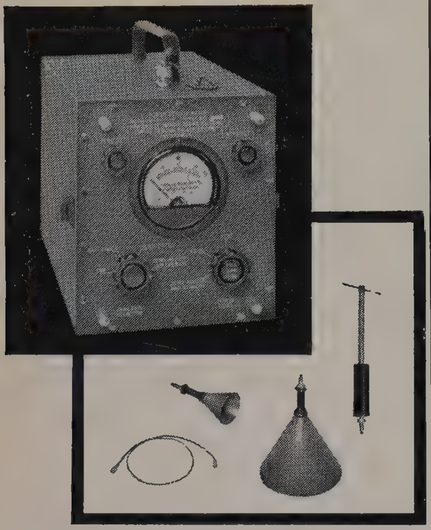
THE McMILLAN COMPANIES

BROWNVILLE AVENUE • IPSWICH, MASSACHUSETTS

Circle Reader Service Card 74

BROADBAND POWER DENSITY METER Model NF-157

For fast, accurate determination of RF power density and location of areas presenting RF hazards to personnel



Description: **A broadband device providing direct reading of RF power densities from 1 mw/cm² to 1000 mw/cm² (mid-scale readings), over the continuous frequency range from 200 to 10,000 MC.**

Features:

- Direct reading of power density insures immediate awareness of hazardous areas.
- Broad frequency range and high accuracy permit universal application to mapping of high level RF fields from VHF to X-Band.
- Accurate built-in step attenuator provides capability of handling power densities over a dynamic range of 10,000 to 1.
- Three constant-gain calibrated probes permit direct reading in mw/cm² over the continuous frequency range from 200 to 10,000 MC.
- Physical separation of probes from main unit vastly increases flexibility of applications.
- Battery-powered, light-weight design permits complete portability.
- Convenient carrying case simplifies transportation of instrument.
- Efficient shielding prevents stray RF pickup.
- Conservative design insures resistance to over-load.
- Main unit may be used independently as an accurate, rugged RF power meter over a wide power range.

Send for our Catalog No. 614

edp EMPIRE DEVICES PRODUCTS CORPORATION

AMSTERDAM, N. Y. Victor 2-8400

MANUFACTURERS OF FIELD INTENSITY METERS DISTORTION ANALYZERS • IMPULSE GENERATORS COAXIAL ATTENUATORS • CRYSTAL MIXERS

Circle Reader Service Card 75

New Products

(*Continued from page 120*)

the frequency range from 5.25 to 5.75 Gc and is rated for a peak power of three megawatts when pressurized to 30 psig of air, and 10 megawatts when pressurized to 20 psig of sulfur hexafluoride.

A special feature of these rotary joints is a rotary feed through along the joint axis. This can be a solid rod used to indicate the angular position of the antenna or it can be made into a coaxial line to provide one or more low power signal channels. The use of special ball-bearing supports results in reduced WOW (less than ±0.05 at 1.15 VSWR) and low maximum starting torque of only 1.25 inch-lbs. at 30 psig for Model S 60-1. VSWR in each of these three joints is less than 1.15.

Two other bands from 1.27 to 1.40 Gc and 8.5 to 9.5 Gc are also available, in either aluminum or brass, in this "family" of rotary joints.

Circle Reader Service Card 130

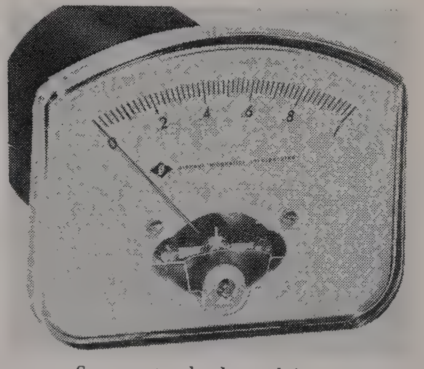
— m w j —

PIONEER OFFERS MAGACYCLER-METER

The Magacycler-Meter, a completely self-contained precision frequency to analog transducer with an integral indicating meter, is now available from Pioneer Magnetics Inc., Santa Monica, Cal.

The Magacycler-Meter uses only rugged static elements to produce a dc meter current which is directly proportional to the input frequency or pulse rate. Accuracy and stability are guaranteed. With the standard 2 1/2 inch D'arsonal meter, the accuracy is ± one per cent of full scale. With larger instruments, accuracies of ±1/2 per cent are available.

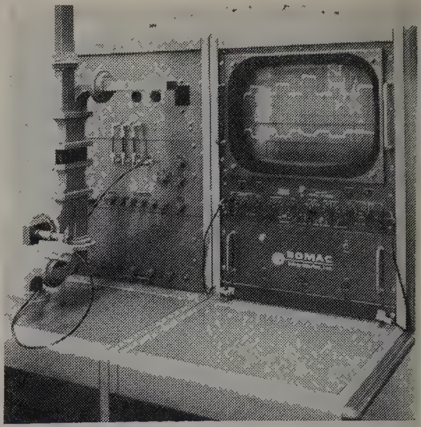
The maximum frequency detected can be adjusted by the customer through a four-to-one frequency range by means of a built in attenuator. Thus model MM-1000-D has a range of 0 to 250 cps to 0 to 1000 cps. Full scale deflection can be obtained at any desired frequency between 250 and 1000 cps. Once the full scale frequency has been set, the output will vary linearly from zero to 100 per cent meter deflection as the input frequency varies from zero to the full scale maximum. Seven standard models cover the audio range from 15 cps to 12,000 cps (to 100 kc upon request).



Circle Reader Service Card 131

— m w j —

BOMAC OFFERS TR TUBE TESTER



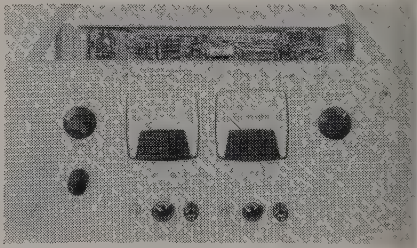
The BLP-043K, a test set for low-level production testing of single and dual TR tubes at five pre-selected frequencies, is being offered by Bomac Laboratories, Beverly, Mass.

The set is used to measure, with extreme rapidity, the isolation or insertion loss and VSWR of the tube under test. Two test results are displayed on the oscilloscope simultaneously, speeding product testing. In addition, hourly cost of operation is reduced, since relatively inexpensive klystrons are used as oscillators.

Circle Reader Service Card 132

— m w j —

LABORATORY REGULATED POWER SUPPLY ANNOUNCED



PRL Electronics, Inc., Rahway, N. J., announces a Laboratory Regulated Power Supply rated at 0 to 600 Volts DC at one Ampere maximum, on an 8 3/8 inch panel for relay rack mounting, designated as Model RTS-601.

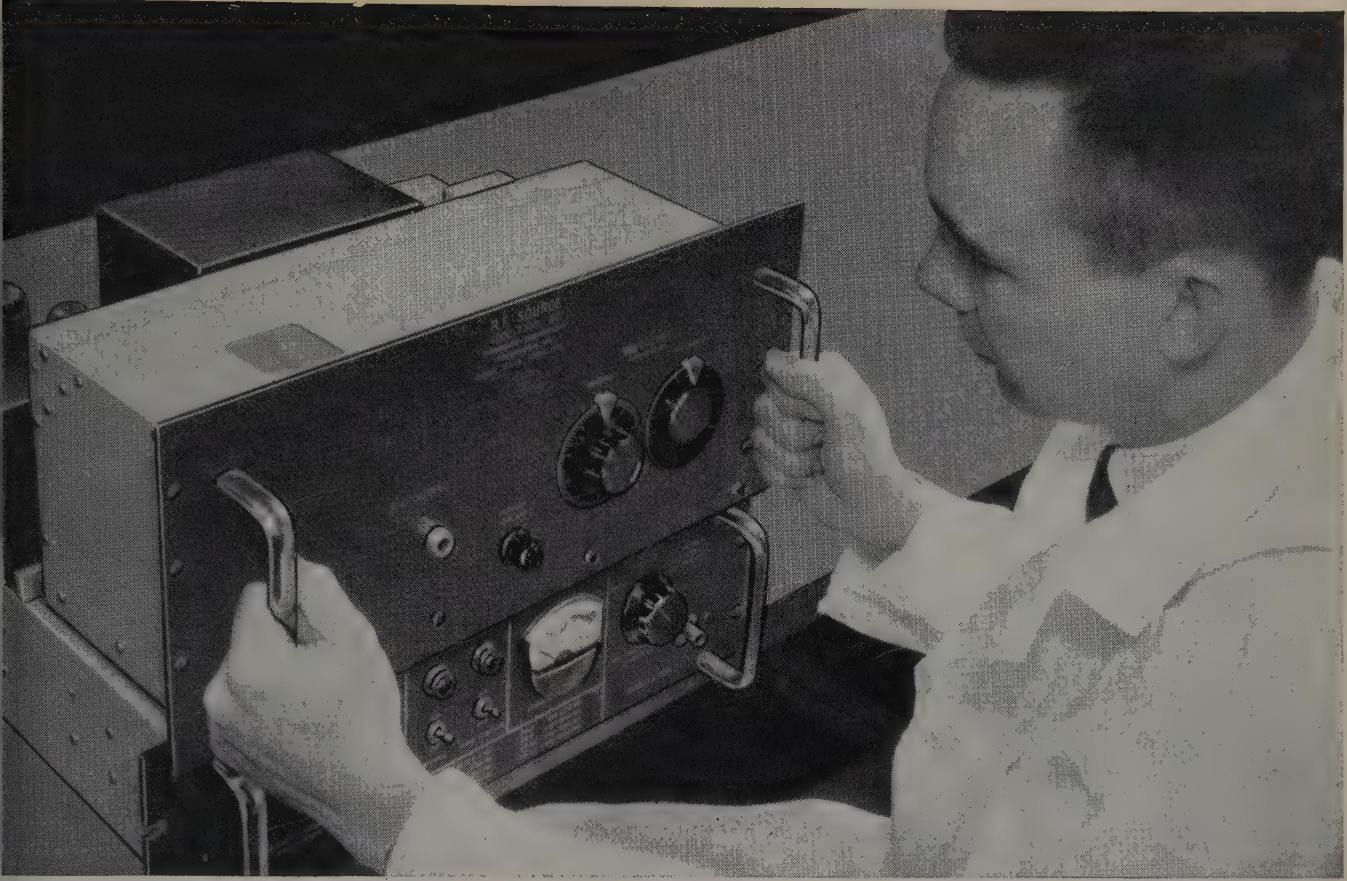
Regulation for input line voltage variations of ±10 per cent is ±0.05 per cent or ±20 millivolts, whichever is greater. Regulation for a no load to full load change is 0.05 per cent or 50 millivolts, whichever is greater. Ripple is less than one millivolt RMS. A bias output of 0 to 150 Volts DC and two 6.3 Volt RMS 10 Ampere filament outputs are also provided.

Model RTS-601 features remote programming (850 ohms/volt) and remote sensing. A pair of four-inch rectangular two per cent full scale accuracy meters are mounted on the front panel. The RTS-601 is priced at $854.00 each for rack mounting, and cabinet housed the price is $889.00 each.

Circle Reader Service Card 133

— m w j —

(*Continued on page 129*)



New Weinschel Plug-in RF Sources for Precision Microwave Measurements provide exceptional amplitude and frequency stability, cover a wide frequency range with true single knob control.

Six new RF Sources, which cover the frequency range of 50 to 10,500 MCS and plug into a common Power Supply-Modulator, have been developed by Weinschel Engineering to meet the demand for stable sources for CW or 100% square-wave modulated RF Power for precise microwave measurements.

For ease of operation, the Power Supply-Modulator, Model MO-3, automatically selects the proper meter range and all the voltages necessary to operate each of the RF Sources without adjustments, thus providing true single knob control. In addition, when a source is plugged into the Power Supply-Modulator, the application of high voltages is automatically delayed until the warm-up of tube filaments is complete.

Klystrons are used above 900 MCS. Castings with integral bearings provide for all moving parts a rigid support which is independent of possible bending of the panel. This rugged construction results in maximum amplitude and frequency stability. The super-honed cavities and non-contacting, low loss, Z-type shorts assure long, reliable and maintenance-free service.

Key Specifications are: *(After 30 minutes' warm-up)*

Stability of output power (both CW or Modulated): Better than 1% in 8 hours (for constant load).

Stability of Frequency of 1000 cps Modulator: Better than .01%.

Frequency Stability: 50 to 920 MCS: better than ± .1%. 900 to 10,500 MCS: Better than 1 part in 10^4 in 8 hours, better than 1 part in 10^5 in 15 minutes.

		FOR 50 OHM LOAD	
MODEL NO.	FREQUENCY MCS	MINIMUM POWER OUTPUT, CW	MINIMUM PEAK POWER OUTPUT (100% Square Wave Modulated)
MS-12	50-250	40 MW	40 MW
MS-13	250-920	100 MW	100 MW
MS-8	900-2200	20 MW	20 MW
MS-9	2100-4200	2100-2600 MCS: 30 MW 2600-4200 MCS: 50 MW	2100-2600 MCS: 30 MW 2600-4200 MCS: 50 MW
MS-10	4000-7300	50 MW	50 MW
MS-11	7200-10,500	7200-7400 MCS: 20 MW 7400-9700 MCS: 50 MW 9700-10,500 MCS: 20 MW	7200-7400 MCS: 20 MW 7400-9700 MCS: 50 MW 9700-10,500 MCS: 20 MW

Write for complete specifications.

WEINSCHEL ENGINEERING ®

WE CO

KENSINGTON, MARYLAND Phone: LOckwood 4-0121 TWX Kensington, Maryland 446

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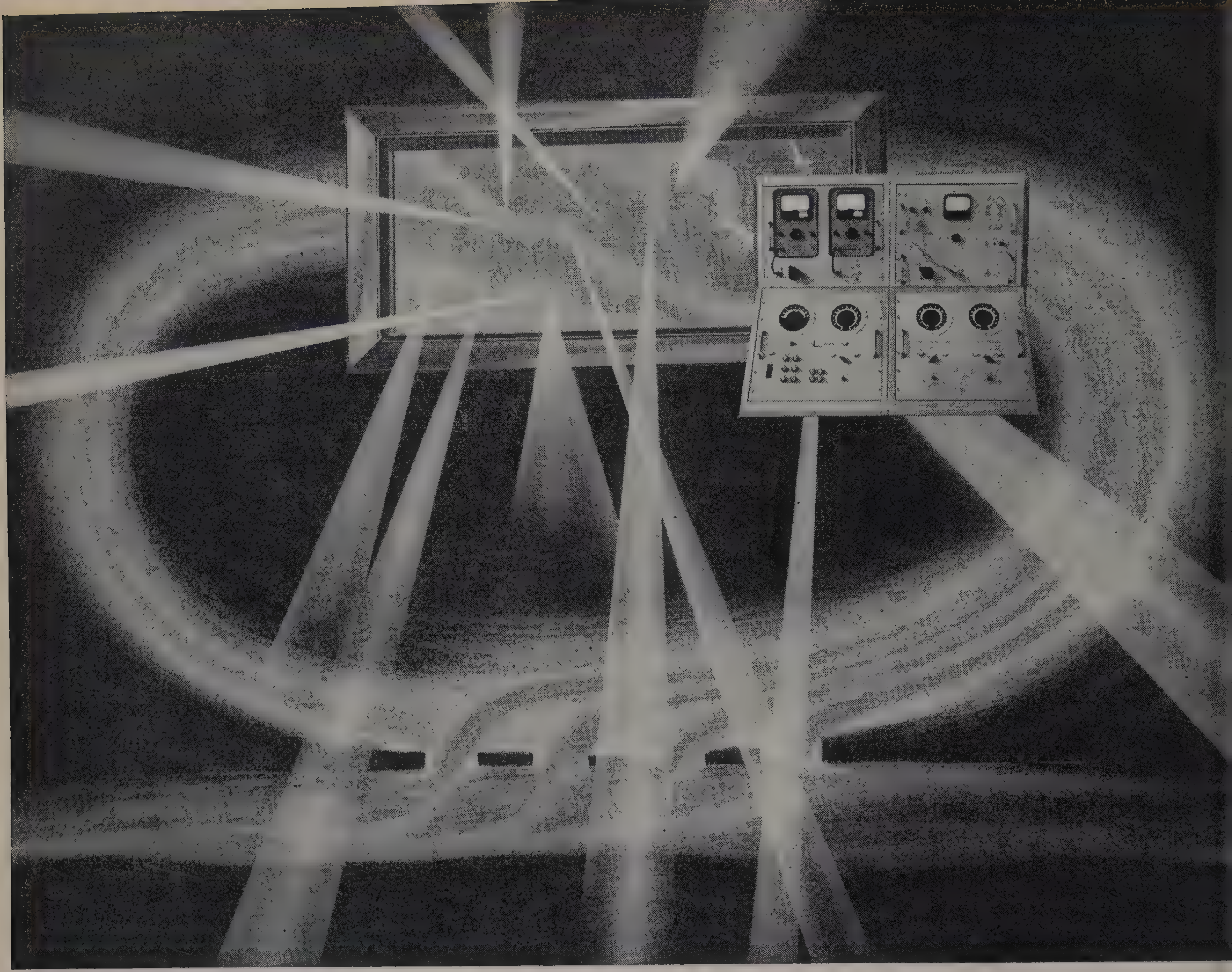


MICROWAVE SYSTEM CAPABILITY

. . . in large waveguide

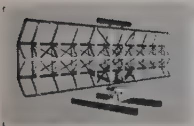
Graphically illustrated above, the resonant ring is an example of I-T-E's ability to design and produce complex microwave systems in large waveguide. This specific unit is used for testing microwave components and networks. It has an extremely high Q, and features precision control of *all* tuning components from the console.

The waveguide plumbing used on an electron accelerator is another example of complex microwave systems. These utilize a wide range of I-T-E large waveguide and rf components such as phase shifters, couplers and other types.

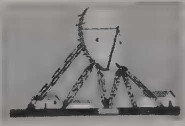
The engineering experience and production facilities of I-T-E are particularly adapted to the design and fabrication of all types of large waveguide. These include test equipment components, feed horns, diplexers and special configurations to performance specifications. For the answer to your waveguide requirements call GArfield 6-5700 or write I-T-E Circuit Breaker Company, Special Products Division, Dept. MJ, 601 E. Erie Avenue, Philadelphia 34, Penna.

I-T-E CIRCUIT BREAKER COMPANY

SPECIAL PRODUCTS DIVISION

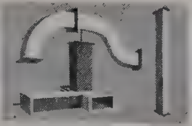


RADAR ANTENNA SYSTEMS



UHF ANTENNA SYSTEMS

PEDESTALS DRIVES • CONTROLS



WAVEGUIDES & COMPONENTS

RESEARCH & DEVELOPMENT

DESIGN & ENGINEERING

PRECISION MANUFACTURING

Circle Reader Service Card 77

COMPANY PROFILE

TRANSCO PRODUCTS INC.

Los Angeles, California

Engineer Hal Summers (left) and project engineer William Stuckey are shown running patterns on a high temperature blade antenna developed for BuWep.

The story of Transco affords an excellent example of American private enterprise at work. Founded in 1942, with offices in California and New Jersey, and manufacturing in Colorado, the company derived its name from the fact that its founder, Marshall W. Sawyer, was almost continuously in flight across the country in his efforts to get the young concern started. Transco is short for "transcontinental." Each phase in Transco's growth in the succeeding years has been accomplished through the vision and risk of its own management.

When manufacturing moved to Los Angeles in 1946, several of the company's projects were for the F-80, and presented difficult design and materials problems. Reginald Kenway, then a materials specialist engineer at Lockheed, and from 1942 to 1946 in charge of all material substitution, was brought into Transco to solve the problems. He has remained to become R&D Vice President, contributing his analytical capability and experience to the success of the company.

An interesting project of this period was the "bean bagger." Packaging in polyethylene bags was then new and unusual, and Transco developed a hydraulic and electromechanical "wonder machine" which would automatically measure, package, and seal beans or similar products in bags of this material. Kenway was joined by Norman Dickey, present senior mechanical project engineer, in developing this automatic food packaging machine.

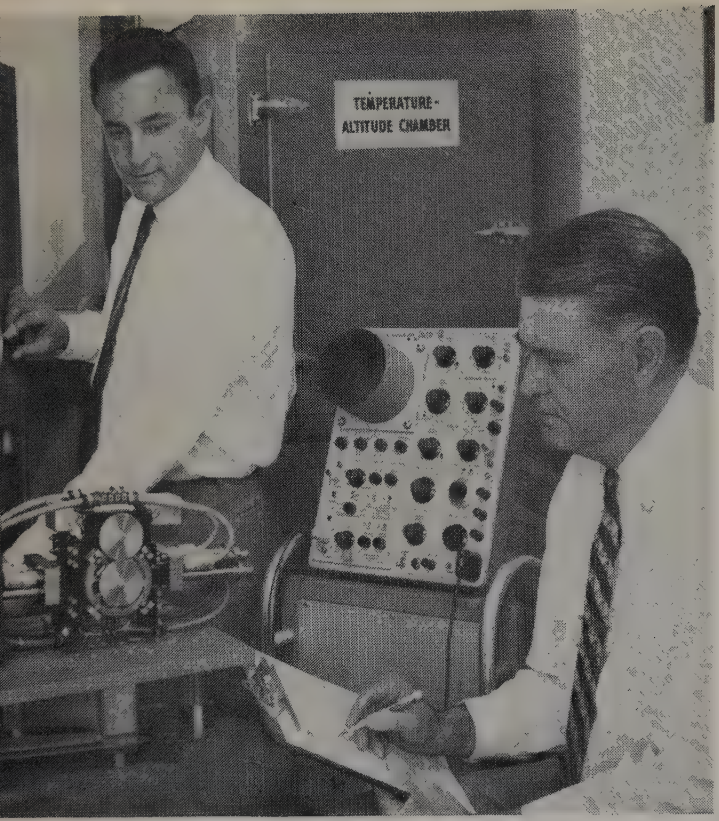
These same two men, Kenway and Dickey, collaborated to develop a series of hot air valves for the F-80 and F-94. Further development based on these projects has resulted in the current, extensive line of hot air valves.

Transco Enters the Microwave Field

The step into the microwave field was taken in 1947 when Marshall Sawyer and Reginald Kenway were shown a drawing by a customer. The official to whom they were talking showed them prints which he was having trouble reading; asking their assistance. Sawyer now admits that he too had some trouble reading the prints, but Kenway not only understood; he said Transco could build the product . . . a microwave antenna array.

Transco soon entered a new field, accomplishing the mechanical design and manufacturing antennas for the Lockheed P2V from designs supplied by Airborne Instruments Laboratory. Discussions with microwave systems engineers regarding antennas brought out the fact that there was a serious need for another type of microwave product . . . a dependable, light weight coaxial switch.

The mechanical and electromechanical skills of Transco personnel were combined with newly gained RF knowledge to develop a new coaxial switch that would meet this requirement. The E-Type, with motor actuation, was produced first; then the Y-Type, with solenoid actuation.



Mel Scott, engineer, and Norman Dickey, project engineer, check vibration test on a quadrant lobing switch.

These switch designs, which helped establish Transco as a leader in the microwave switch field, are still manufactured today, although, of course, they have undergone numerous improvements.

People and Products

Marshall W. Sawyer, President, has been the guiding hand of Transco from its beginning during World War II to the present. His recognition and support of good electromechanical design has established an excellent product line. His firm financial policies have built a strong, well financed company which can enter most programs without the need for additional financing. He sees Transco as a company possessing the capability to produce any electromechanical or microwave device and not necessarily restricted to the products presently manufactured.

Reginald Kenway, R&D vice president, using his extensive knowledge and experience in the electrical and communications fields, pioneered the design and development of the Transco motor driven coaxial switches and later the revolutionary miniature solenoid operated coaxial switches. His other projects have included antennas, matching networks and delay lines. Kenway was project engineer for the THOR antenna systems which were developed, manufactured, and tested at Transco from Stanford Research Institute studies.

Harold W. Bauman, engineering vice president, BSEE University of Wisconsin, joined Transco in 1954 as chief engineer. He directed the design of coaxial switches and took an active part in the initial effort in original antenna design. Bauman came to Transco from Stanford Business Machine Mfg. Co., where he was a vice president. His background includes management of a special projects group for the Signal Corps, directing application of radar IFF, beacon antennas, and ECM equipment design; also supervisory engineering experience at both Bell and Howell and Ampro Corp.

Frank Atha, assistant Chief Engineer, BSEE Purdue University, came to Transco in 1958 after nine years experience with Douglas Aircraft Company, El Segundo Division, where he was group and staff engineer. Assignments at Douglas include antenna installations for all communication and navigation equipment. His Transco assignments have included a Multiplex System—antenna, antenna selector, coaxial switch, lobing switch, and filter for IFF-TACAN.

Edward Malherbe, project engineer, BSE, U.C.L.A., is a mechanical engineer specializing in electrical and mechanical actuators. Malherbe was project engineer on the F-100 landing lights supplied by Transco. He is presently in charge of actuator design for microwave products and mechanical design of high temperature blade antennas for IFF-TACAN.

George M. Underberger, project engineer, BSEE Pacific States University, came to Transco from Kearfott Division of General Precision where he was manager of the Systems Engineering Laboratory. He has been active in the microwave field for over 10 years and is past chairman of the Los Angeles IRE Chapter of the Professional Group on Microwave Theory.

William Stuckey, project engineer, Registered Professional Engineer, came to Transco after nine years with Lockheed Aircraft Co. in electronic design. As a senior antenna research engineer, Stuckey has had extensive experience with all types of airborne antenna systems design and development. At Transco, he has conducted radiation pattern studies for the XB-70 CNI antennas and is project engineer on the BuWep antenna contract.

Transco has attracted a highly versatile group of engineers with the incentive of creative opportunities and recognition for individual accomplishment. Engineers, electrical or mechanical, must understand all aspects of a project. All engineers have the opportunity to follow their projects through from initial talks with the customer to proposal preparation and product design . . . and to see the product manufactured. The services of outstanding engineers and physicists are employed on special projects to augment Transco's own engineering staff.

Current Activities

Current activities at Transco include three major programs in the antenna area and three in the microwave sub-system area. Other activities are centered around the expansion of the microwave switch and component product lines.

The three antenna programs are (1) CNI antenna systems for the B-70, (2) an R&D antenna development program for high speed antennas for the Bureau of Naval Weapon Systems, and (3) a data link antenna system with antennas and switches, contained in one easy-to-mount package, for the F-101.

The microwave sub-systems are (1) a waveguide and coaxial switch assembly for antenna switching of the ALQ-41 and ALQ-51 in the A3D, (2) a C-Band Transponder check-out set to test the missile transponder as

TRANSCO PRODUCTS, INC.
12210

Front of Transco facility in Los Angeles.

part of the AZUSA system, and (3) a ground check-out delay line with two delays remotely selectable for the BOMARC.

Transco manufactures a most extensive line of microwave switches — more kinds for a broader range of applications than any other company. Coaxial switches which operate through 11 kMc are manufactured in SPST to SP6T, and transfer configurations with manual, motor, or solenoid actuators. Eight different connector types are available as well as a host of special variations. Latching switches (that require no holding power), switches with indicator circuits, and switches for a large variety of cable sizes are also available. An interesting new coaxial switch design is the Type-W . . . an SPDT latching switch only 3/4 x 2 1/2 x 3 inches and a transfer switch only 1 3/4 x 1 3/4 x 2 1/4 inches.

Facilities

Sales in 1959, approximating $3,000,000, brought profits enabling the recent modernization of the entire facility. A $75,000 expansion program was carried on simultaneously, adding 2000 square feet to permit enlargement of the microwave testing laboratory and engineering offices.

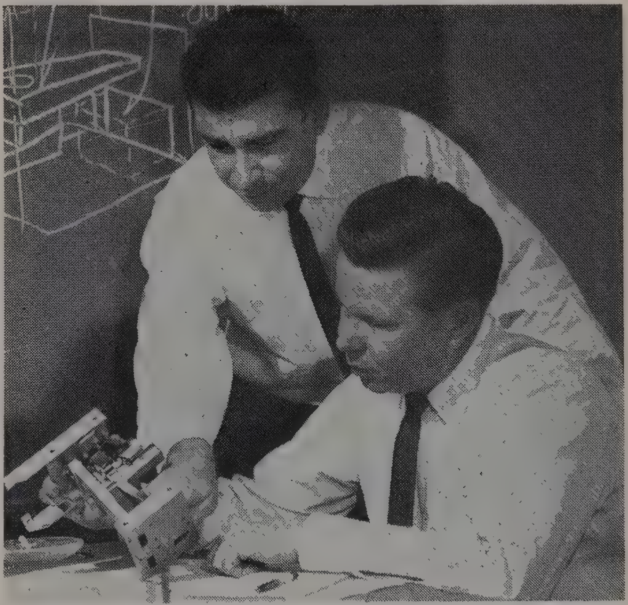
Complete design, development, test, qualification, and manufacturing facilities are housed under one roof. Cost accounting and quality control systems are approved by major aircraft and electronics companies, Air Force, Army, and Navy. The company maintains its own environmental test laboratory, considered to be one of the most well equipped of its kind, devoted solely to intra-company testing.

Marketing Philosophy

Marshall Cleland, vice president, with the company since 1946, has defined Transco as "basically a manufacturing company; one which relies heavily upon its own engineering department to provide new product designs." He feels that a manufacturing company offers an important advantage to the customer when doing R&D or design engineering — "the advantage of designing economically produceable hardware."

Cleland notes the company's emphasis on reliability and quality control as an important advantage in handling the stringent product performance requirements of the missile and space field. Transco maintains an 8 to 1 ratio of inspection to manufacturing personnel. A recent quality control survey by a major electronics company gave Transco the near perfect rating of 96 per cent.

About 80 per cent of sales are proprietary items, but these are frequently qualified to customer specifications. Transco's complete facilities (design through full production) make it possible to enter a program at any phase — design, development, test, qualification, or manufacture. The combination of complete facilities under one



Project engineers George M. Underberger and Edward Malherbe discuss new ECM coaxial and waveguide switch assembly.

MICROWAVE SYSTEMS
ANTENNAS

The lobby of Transco's Los Angeles facility.

roof, technical versatility, and moderate size permit fast action when production quantities are required on a short time schedule.

Although Transco products are often used for laboratory tests, the company does not compete in the laboratory test equipment area. Transco follows a policy of cooperating with customers in the cost of product development where the product is considered to have a wide application.

Transco has representatives throughout the United States and Canada which are supported by regional sales engineering offices in the New York, Dayton and Los Angeles areas. These regional engineering offices in key locations across the country maintain the company policy of technical liaison from concept to the delivered product.

Reginald Kenway, vice president of R&D; Frank Atha, assistant chief engineer, and Harold Bauman, vice president of Engineering (left to right) confer on a new data link antenna design.

Looking Ahead

The future looks bright for the microwave field in general (fastest growing portion of the electronics industry) and for Transco in particular. Transco's position as a leader in the development and manufacture of microwave switches has been bolstered by several recent significant improvements in both the coaxial and waveguide switch areas.

A revolutionary new Transprobe switch, conceived and developed by Transco, provides new flexibility, smaller space requirements and lifetime dependability through the application of probe coupling to waveguide switching. This principle (probe coupling), which has been used for transitions and rotary joints, was adapted by Transco to microwave switching.

Knowledge gained from sub-system contracts, such as the delay line and ASUZA transponder check-out set, opened new doors for Transco. The Naval Bureau of Weapon Systems' R&D contract for antennas to meet supersonic environment and development of the CN antenna systems for the B-70 give Transco an invaluable background of experience in anticipation of the next generation of air-borne antennas. Transco experience with ballistic missiles is extensive (THOR antenna systems), and successful operation of a Transco switch aboard the Pioneer V places the company firmly in the space field.

During its 19th year of operation, Transco gives every indication of being a mature, well balanced organization which has pioneered in new fields and found the capability and resources to reach successful conclusions in the form of both advanced designs and successful production. It is indeed one of the year's finest examples o "private enterprise at work."

(*Continued from page 122*)

GE MARKETS ERROR-REDUCING TRANSISTORIZED MICROWAVE SYSTEM

General Electric Co., Communication Products Dept., Lynchburg, Va., is marketing an error-reducing transistorized microwave radio relay system that provides a ten-fold increase in transmitter power output but requires 50 per cent less power input.

The new system virtually eliminates transmission errors to achieve a new high in reliability. It slices maintenance by 40 per cent to reduce operational expense. Equipment size has been cut in half through transistor circuits and modular plug-in construction, decreasing floor space requirements and lowering installation costs and time.

Built for high channel capacity and medium to long haul use, the new design has been designated the RF-7 and transmits at frequencies from 5925 to 8400 megacycles.

The RF-7 system is engineered to provide flexibility for expansion and future developments in communications automation. Through transistorization, it accents reliability for voice, data, teletype, facsimile and telegraph applications.

Circle Reader Service Card 134

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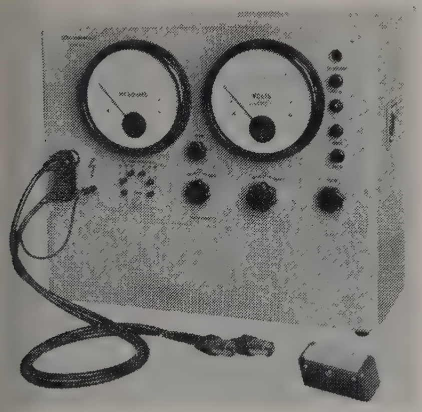
ROHDE & SCHWARZ ANNOUNCES TERAOHMMETER



The Teraohmmeter, an insulation measurements instrument, was recently announced by Rohde & Schwarz Sales Co., Inc., Passaic, N. J.

Designed for accurate resistance measurements, the Jahre Teraohmmeters cover the range two Megohms to 500 Teraohms (5 x 10^{15} ohms) at potentials up to 1000 volts. The instrument uses a single tube, built to the manufacturer's exacting specifications, to provide maximum stability. The Teraohmmeter is direct reading, with a guaranteed accuracy of three per cent over the center one-third of its logarithmic-type scale, and is warranted for one year against defects.

Two seven-inch meters, of 0.5 per cent accuracy, are used for voltage and resistance indications. The Teraohmmeter automatically sums the capacitive, electron, ion and surface components of current through the material under test. From this current and the tube parameters, the resistance scale is calibrated.

Circle Reader Service Card 135

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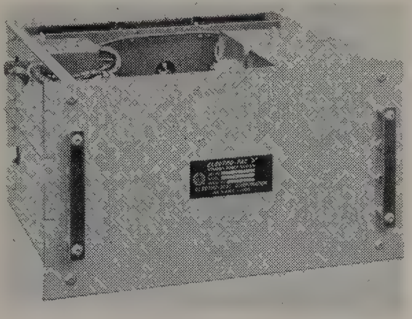
STANDBY POWER SYSTEM PROVIDES ZERO SWITCHOVER TIME



Designed expressly for the needs of electrical and electronic systems where power interruption of even a single cycle will destroy intelligence sequences, a new standby power system which cuts in with zero switchover time when the ac line drops below a pre-set level, has been announced by the Electro-Seal Corp., Des Plaines, Ill.

The Electro-Pac "A" standby power system provides ac from the battery source, regulating the voltage to ± seven per cent. There is three per cent maximum harmonic distortion in the sine wave output produced by this solid state device. Transistors and silicon controlled rectifiers have eliminated the need for moving parts.

When the ac line voltage returns to normal, the Electro-Pac "A" first synchronizes itself with the line frequency, then automatically switches the load back to the ac line and returns to a standby state. When in this standby state, the Electro-Pac "A" serves as a line voltage regulator holding the ac applied to the load within ±three per cent. Likewise in the standby state, this device will suppress harmonic distortion on voltage applied to the load within ±three per cent.

Designs with outputs from 500 va to three kva are available. For higher powers, units may be operated in parallel.

Circle Reader Service Card 136

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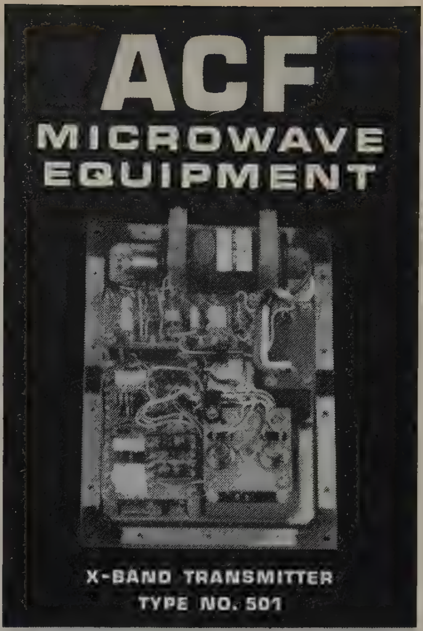
(*Continued on page 130*)



COMPACT DESIGN WITH NO PERFORMANCE PENALTIES. SYSTEM-TESTED FOR OPERATIONAL SPACE VEHICLES. ENGINEERED TO MEET COMPLETE MILITARY MISSILE SPECIFICATIONS.

Frequency Range: 8900 mc to 9400 mc
Wave Guide Power Output: 1,000 Watts, peak
Duty Cycle: 0.002 (maximum)
Pulse Width: 0.45 u seconds ± 0.1 u seconds
Minimum Pulse Spacing: 90 u seconds
Modulation: Pulse
Modulator: Solid State
Input Voltage: 24-30 V DC @ 1 amp.
6 V DC @ 0.45 amp.

May be operated as a free-running pulse transmitter or used with a commutator type telemetry unit capable of providing PPM triggering signals at rates up to 900 bits/sec.

Standard designs modified to meet specific requirements. Complete manufacturing and engineering resources supported by local field service. Full line of components for L, S, C or X-Band Frequencies.

ACF Beacons have qualified for more major satellite and missile programs than any other beacon.

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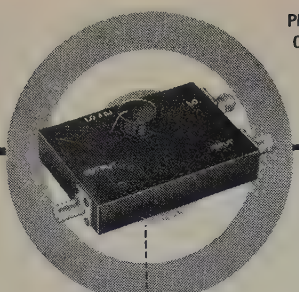

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Buy Performance First

In 20 years in this specialized field, Premier has developed unique skills, facilities and design engineering abilities. Whether a standard waveguide unit or an intricate new design, bring your problem to Premier.

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Full azimuth and elevation sweeps. 360 degrees in azimuth. 210 degrees in elevation. Accurate to 1 mil. or better over system. Complete for full tracking response. Angle acceleration rate: AZ. 9 degrees per second squared EL.4 degrees per second squared. Angle slewing rate: AZ 20 degrees per sec. EL. 10 degrees per sec. Angle tracking rate: 10 degrees per sec. Quantity in stock for immediate shipment.
Complete description in McGraw-Hill Radiation Laboratory Series, Volume 1, page 284 and page 209, and Volume 26, page 233.

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SCR 584 is in like new condition, ready to go, and in stock for immediate delivery. Fully Desc. MIT Rad. Lab, Series. Vol. 1, pp. 207-210, 238, 284.

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Type CM 706A Freq. 3000 to 4000 mcs. CW output 200 watts mim. Factory New

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1 MEGAWATT-HARD TUBE
Output pulse power 25KV at 40 amp. Max duty ratio: .002. Uses 6C21 pulse tube. Pulse duration .25 to 2 microsec. Input 115 volts 60 cycle AC. Includes power supply in separate cabinet and driver. Fully guaranteed as new condition. Full Desc. MIT. Rad. Lab. Series "Pulse Generators."

MIT MODEL 3 PULSER
Output: 144kw (12kv at 12 amp). Duty ratio: .001 max. Pulse duration: .5, 1 and 2 micro sec. Input: 115v 400 to 2000 cps and 24vdc. $325 ea. Full desc. Vol. 5 MIT Rad. Lab. Series pg. 140.

AN/AAS-6 Infrared Detection System, complete. New $5500.

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500 KW. 1220-1350 MCS. 160 nautical mile search range P.P.I. and A Scopes. MTI. Thyratron Mod. 5J26 Magnetron. Like new. Complete system incl. Spare parts and gas generator field supply.

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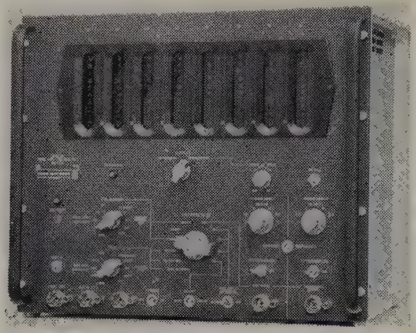
New Products

(*Continued from page 129*)

GENERAL RADIO COUNTER OFFERS CONTINUOUS READOUT



General Radio Company, West Concord, Mass., has introduced its Type 1130-A Digital Time and Frequency Meter, embodying a number of new engineering contributions in counter design.

A high degree of reliability is achieved by new decade codes and high-speed counting circuits; circuits designed to operate under the worst combination of cumulative tolerances imposed by tubes, component values, and voltage levels; use of "hard bottoming" multivibrator dividers for stability; elimination of critical voltages.

The memory in the Counter constitutes an important operating aid. Four of the instrument's eight decades are used for storage and continuous display, while the remaining four decades count continuously. At the end of each counting interval, the total accumulated by the counting decades is transferred automatically to the storage and display decades.

Circle Reader Service Card 137

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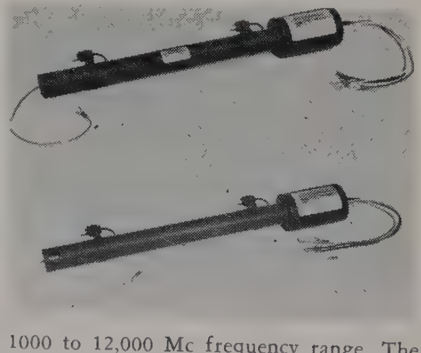
SYLVANIA ANNOUNCES LOW-COST TRAVELING-WAVE TUBES FOR L-BAND

The development of two low-cost, permanent-magnet focused traveling-wave tubes has been announced by Sylvania Electric Products Inc., Buffalo, N. Y.

Mr. R. A. Stonesifer, product sales manager of Sylvania's Microwave Device Operations, said the new L-band amplifiers are part of a series which will cover the 1000 to 12,000 Mc frequency range. The tubes employ integral permanent magnets to reduce their size and weight witho sacrificing electrical performance.



Type TW-4267 (3 1/2 pounds) provid over 15 milliwatts rf output power ar 35 db gain from 1000 to 2000 megacycle Type TW-4268 (four pounds) operat over the same range with more than o watt rf output power and 30 db ga The tubes have a maximum diameter 2 1/4 inches.

Small quantity price for both types $925. Evaluation units are available i mediately, and small quantities can delivered in approximately 60 days.

Circle Reader Service Card 138

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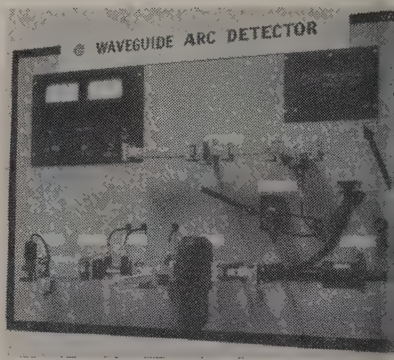
ARC DETECTOR SYSTEM OFFERED BY VARIAN



Radiation Division has announced th addition of a Waveguide Arc Detect System to the product line of Varian A sociates, Palo Alto, Cal. With the syste damaging arcs now may be optically d tected in waveguides and the power tu output reduced in order to extingui arcs and prevent expensive damage.

Waveguide arcs become serious pro lems at high power in CW systems. A though arcing is not fully understoo arcs will travel toward the power sour and present nearly a short circuit in t waveguide. Damage to a power tube ma be caused either by a high VSWR or loc heating of the output window by an ar

The V-9000 Waveguide Arc Detect System covers the frequency between 7 - 7.5 kMc in RG-51/U waveguide. Th sensing unit is mounted on a bend ne the power amplifier output window. I cluded in the sensing unit are two cha nels of solar cells and amplifiers, and test lamp. Amplified signal from the sol cells is directed into a control unit, whic activates a solid-state waveguide swit which removes the rf drive to the pow amplifier tube. Nominal operation tim is 10 - 15 μ sec. A test light circuit chec operation of the entire system.

Circle Reader Service Card 139

—*mwj*—

WELDING POSITIONERS USED IN TESTING RADAR ANTENNAS

The normally difficult and expensive problem of maneuvering heavy, bulky radar antennas for final precision testing has been solved by the use of positioning equipment, originally developed for the welding industry, according to Paul Galton, general manager of the Ransome Co., Scotch Plains, N. J.

Weldors use positioning equipment principally to manipulate heavy and intricate pieces so that they can be tilted to any desired angle, and rotated through a complete circle. These are the very motions required for final testing of radar antennas.

Circle Reader Service Card 140

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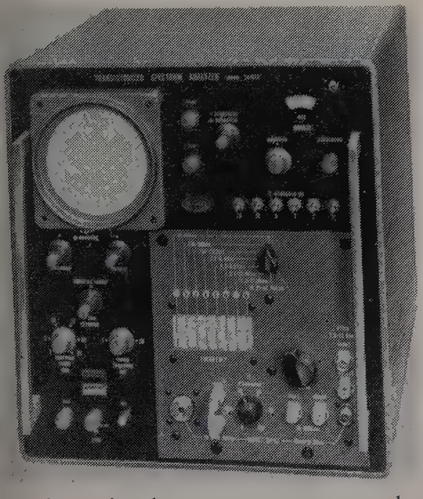
POLARAD DEVELOPS MICROWAVE SPECTRUM ANALYZER

Polarad Electronics Corp., Long Island City, N. Y., has developed a mobile, transistorized, microwave spectrum analyzer. The Model SA-84T Spectrum Analyzer covers the frequency range from 10 - 40,880 Mc.

The instrument is capable of a number of operations, including spectral measurements, detection and identification of spurious signals, countermeasures analysis, measurement of the frequency difference of two RF signals, testing microwave oscillators for pulling, double-moding, and other types of malfunctions, checking the tracking of radar components, and measurement of spectral characteristics of pulse-modulated and FM signals.



This spectrum analyzer is particularly suited to mobile operation because of its light weight (70 pounds), its extensive transistorization, and its acceptance of either standard 12-volt automobile battery power or 115 volt ac power. The SA-84T also incorporates a single tuning unit covering the entire frequency range, a direct-reading frequency dial, a self-contained frequency marker for measuring small frequency differences, a completely transistorized, electronically regulated power supply, adjustable frequency dispersion, single-knob Unidial® tuning, and low incidental frequency and amplitude modulation.

Circle Reader Service Card 141

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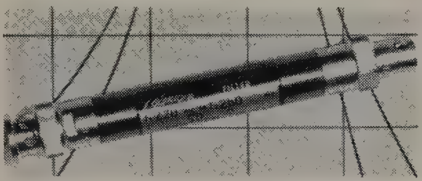
MINIATURE FILTERS DESIGNED FOR TELEMETRY SERVICE

Miniature bandpass filters designed specifically for use with telemetering systems and other transmission applications are now available from Telonic Engineering Corp., Laguna Beach, Cal.



The new filters, Telonic TBP types, are used in transmitters to reduce spurious output signals from pickup or other sources. Filter characteristics, such as center frequency, bandwidth and cutoff, may be varied to meet individual requirements. Center frequencies are available covering the 200 - 2000 Mc region with bandpass widths of 2.5 - 20 per cent.

The ability of the TBP filters to withstand shock, vibration, acceleration, and temperature cycling makes them ideal for use in both ground and airborne transmission systems.

Circle Reader Service Card 142

—*mwj*—

HIGH PRESSURE FLEXIBLE WAVEGUIDES NOW AVAILABLE

High pressure flexible waveguides for use in the field of high power radar have been introduced by Electronic Specialty Co.'s Technicraft Division, Thomaston, Conn. The units utilize 45 pounds pressure for L-Band application (1.2 - 1.70 kMc).

Operating at 50,000 watts CW and 25 Mw peak power, the waveguides are available in production quantities in a wide variety of flange combinations.

Prototyped and tested at MIT Lincoln Laboratories, the units are currently in production for the NIKE-ZEUS program. In addition, substantial orders have been received from several large firms in the industry.

Circle Reader Service Card 143

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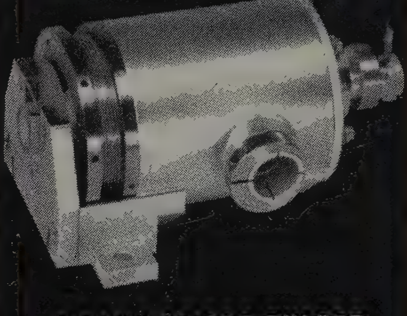
ACF
MICROWAVE
EQUIPMENT



C-BAND TRIODE PULSED
OSCILLATOR MODEL NO. 338

SPECIFICALLY DESIGNED FOR TRANSMITTER SERVICE IN MISSILE AND DRONE TYPE RADAR BEACONS.

Maximum miniaturization with no performance penalties. System-tested for operational space vehicles. Engineered to meet complete military missile specifications.

Frequency Range: 5400 to 5900 mc
Power Output: 1.5 kw min. (200 mc tuning range)
1.0 kw min. (500 mc tuning range)
Stability: ± 3 mc over the most stringent air-borne environmental conditions.
Pulling Factor: Less than ± 2.5 mc for 1.5 VSWR, all phases.
Pushing Factor: Less than 5 kc/peak ma.
Load Variation: Can withstand VSRW's of 6:1 at any arbitrary phase without impairing life expectancy.

Standard designs modified to meet specific requirements. Complete manufacturing and engineering resources supported by local field service. Full line of components for L, S, C or X-Band Frequencies.

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NEW LITERATURE

MICROWAVE TOWER INSPECTION CHECK LIST AVAILABLE

A microwave tower inspection and maintenance check list is being offered free to any interested firm by the Tower Construction Company, Sioux City, Iowa

The check list is a handy pocket size booklet which is useful to those involved in inspection and maintenance of microwave towers. The list emphasizes what should be checked, and the frequency with which inspection should be made on all parts of the equipment.

The check list points out what to look for; how to detect and how to repair or replace that which inspection shows needs correction.

—*mwj*—

UNINTERRUPTED POWER SUPPLIES DESCRIBED IN CATALOG

A brochure describing available Uninterrupted Power Supplies has been issued by the power equipment division of Consolidated Diesel Electric Corp., Stamford, Conn.

An Uninterrupted Power Supply, unlike an ordinary automatic standby diesel-generator set, provides absolutely continuous power in the event normal power sources fail. It does not require the diesel engine to start and come up to speed before assuming the electrical load. Rather, kinetic energy stored in a flywheel provides power during the interval required for the diesel engine to reach full power.

Two types of UPS units are described in the Condec catalog. For most applications Condec recommends a type in which a single synchronous dynamo functions as a motor to drive the flywheel during normal operation and as a generator during commercial power outages. When floating on the line, the dynamo can also serve as a synchronous condenser.

Circle Reader Service Card 165

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RAYTHEON HANDBOOK DESCRIBES LOW-POWER TUBES

A handbook, published for design engineers, with complete descriptions of low-power tubes for industrial, military and communications applications, has been made available by Raytheon Co.'s Industrial Components Division, Newton, Mass.

Besides charting all specifications, the eight-page booklet also diagrams each tube's base and envelope connections.

Low-power transmitting tubes, series regulators, rectifiers and clipper tubes are included in the three-color handboo which also discusses military specificatio and quality control techniques Raytheo tubes are required to meet.

Circle Reader Service Card 166

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CONDENSED CATALOG AVAILABLE FROM LITTON

Litton Industries' 1961 Electron Tu Condensed Catalog is available from ti Litton Industries Electron Tube Divisio San Carlos, Cal.

Quick reference specifications an photos are provided in the 16-page catalo describing the Litton Tube Division's complete line of microwave tubes, displa devices and operational accessories. Mill meter wave tubes and monitor diode available through the Electron Tube Division, also are described.

Circle Reader Service Card 167

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BULLETIN 600 AVAILABLE FROM PRD

A four-page, three-color, Bulletin 600 i available from PRD Electronics, Inc Brooklyn, N. Y., which categorizes PRD complete line of waveguide and coaxia bolometers, thermistors and mounts.

Featured are many coaxial and waveguide crystal mounts for high efficienc power measurements and accurate detection, covering a wide frequency rang from 0 to 40 kMc/s.

Charts and photographs indicate frequency, RF power, VSWR, operation resistance, bias current, dimensions, length etc.

Circle Reader Service Card 168

—*mwj*—

WESTINGHOUSE OFFERS BROCHUR ON SWITCHING TUBES

Characteristics and application data fo high-vacuum switching tubes for puls modulation make up a new brochur available from the Westinghouse electronic tube division, Elmira, N. Y.

The brochure includes summarize characteristics for 19 tube types — 15 tr odes, 2 tetrodes and 2 diodes — and useful bar-chart showing relative pea power capabilities for all tubes in th group. Peak power of tubes covers range from 7.5 kw for the WL 6293 to 37. Mw for the WX 4450 and WX 436 tubes.

Circle Reader Service Card 169

—*mwj*—

(*Continued on page 136*)

from Pyrofilm . . .
unlimited carbon film*
MICROWAVE
RESISTOR DESIGNS
* TWICE THE POWER
IN HALF THE SIZE
- Ideal for coaxial low and high frequency attentuators, terminations, waveguide attenuators and probes.

RODS
DISCS
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Resistance range:
.2 to 10,000 ohms

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420	2.0 to 4.0 Kmc	10 mw (min)	Type N
430	4.0 to 8.0 Kmc	10 mw (min)	Type N
440	6.5 to 11.5 Kmc	10 mw (min)	Type N
450	8.2 to 12.4 Kmc	10 mw (min)	Type N or Waveguide UG-135/u
460	12.4 to 18.0 Kmc	10 mw (min)	Waveguide UG-419/u

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BOEING

New Literature

(*Continued from page 132*)

LITERATURE ON TRACKING TELEMETRY RECEIVER AVAILABLE

Literature on the Type 1440 Satellite Tracking Telemetry Receiver is announced by Vitro Electronics, a Division of Vitro Corp. of America, Silver Spring, Md.

Data Sheet C-006 describes the new FM crystal controlled Phase-Lock telemetry receiver which features a low noise figure of six db. It has a tuning range from 130-140 Mc covering the recently assigned satellite band. The uniform stable and accurate tuning characteristics over the entire range make this receiver ideal for tracking telemetry signals from instrumented space vehicles operating within the range.

The receiver is designed for mounting in a standard 19-inch rack. It measures 19 inches wide, 8 3/4 inches high and 16 1/8 inches deep. Weight is approximately 40 pounds, and it is finished in gray enamel.

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—*mwj*—

ANTLAB BOOKLET LISTS RECENT ADVANCED DEVELOPMENTS

Antlab, Inc., Worthington, Ohio, manufacturer of mechanical and electronic components for missile and satellite tracking systems and antenna pattern range instrumentation, is offering a new short form catalog.

The 20-page booklet lists such recent advanced developments as a new microwave receiver, a new series of 60,000 foot-pound antenna mounts and a series of totally enclosed servo and electro-manual antenna mounts.

Circle Reader Service Card 171

—*mwj*—

CATALOG AVAILABLE ON DK COAXIAL SWITCHES

RF Products, Danbury, Conn., a division of Amphenol-Borg Electronics Corp., Chicago, Ill., has published a 28-page catalog describing its standard line of DK Coaxial Switches and Relays. All are offered for fast delivery from stock.

Among the features of the new color catalog are: a resume of the chief characteristics and operating principles of the coaxial switch, a complete summary of 125 standard switches available from stock, details on production and custom engineering facilities, quality control processes, and information on sales and ordering.

Embodying a new concept in customer service, the DK Coaxial Switch catalog enables the reader to quickly find the coaxial switch needed, together with all necessary information pertaining to it.

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—*mwj*—

FERRITE MICROWAVE COMPONEN CATALOG OFFERED

Caswell Electronics Corp., San Jose Cal., has announced the availability of it new condensed catalog and price list fo ferrite microwave components and sub assemblies.

Contents of the catalog cover specific tions and current price information o the complete Caswell line. Products i clude waveguide and coaxial ferrite lo isolators, mechanical variable attenuato ferrite modulators, adjustable and reversi ble isolators, matched terminators, circ lators and various other components an sub-assemblies.

In addition, details are provided o facilities for research and developme and custom manufacturing for both ferrit and general type devices within the 1 - 1 Gc frequency range.

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—*mwj*—

HUGHES PREPARES WELDING REPORT

A technical report on the metallurgy o electronic welding, prepared by the tech nical staff of Hughes Aircraft Company is now available from the company vacuum tube products division, Oceanside Cal.

The report covers laboratory studie directed by R. D. Engquist, and includes the resistance welding process, significan factors in resistance welding, evaluation o weldability of various materials, welda bility of clad materials, and dissimila materials.

The report is illustrated with photo graphs of magnified welds, and include several charts and graphs.

Circle Reader Service Card 174

—*mwj*—

DRESSEN-BARNES OFFERS POWER SUPPLY CATALOG

A new DC Power Supply Handboo and Catalog is now available fro Dressen-Barnes Electronics Corp., Pasa dena, Cal., to anyone interested in DC power design or procurement.

The 24-page manual includes a step b step procedure designed for engineers who wish to calculate packaging dimension for multiple DC outputs. Consideration include spacing problems for modular DC power supplies under various condition of ambient temperature, external coolin and rated current. The catalog details ove 200 power supplies plus 1,000,000 com binations of kitted modules.

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—*mwj*—

PRD BULLETIN 700 FEATURES WAVEGUIDE FREQUENCY METERS

Bulletin 700, a four-page, three-color descriptive circular, is available free from PRD Electronics, Inc., Brooklyn, N. Y., manufacturer of microwave and electronic test equipment.

This bulletin features the line of coaxial and waveguide frequency meters and describes, in detail, the more than 50 different models from which to choose from in a variety of ranges covering 0.1 to 40 kMc/sec.

Featured, also, are many high precision coaxial and waveguide direct reading frequency meters used for laboratory and production line testing. Calibrated, ruggedized, Mil Spec frequency meters, as well as precision Heterodyne and Frequency Standard Multipliers are also described.

Charts and photographs indicate frequency, type, accuracy, dimensions, length, etc.

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—*mwj*—

RF CONNECTOR CATALOG OFFERED BY KINGS

A 120-page, two-color catalog containing illustrations and full technical data on its complete line of RF Connectors including the revolutionary K-Grip Connector, is now available from Kings Electronics Company, Inc., Tuckahoe, N. Y.

This RF Connector Catalog incorporates detailed information on all of the following series of connectors: BN, BNC, C, HN, LC-LT, LN, N, Pulse, Miniature and Subminiature, Twin Connectors, UHF, Miscellaneous Connectors and Adapters, Adapters to Rigid Line, Waveguide Adapters, Captivated Connectors, Foamflex, Spirafil, Styroflex, Power, TNC, K-Grip, Polarized Fuel Gauge, Coaxial Cable Termination, Radiation Resistant, 125 Ohm High Impedance, and Hermaphrodite.

Also included in this Kings Catalog are Telephone Jacks and Plugs as well as "specials" . . . those connectors designed for specific applications. A 15-page cross-referencing index — Kings-to-Military Numbers and Military-to-Kings Numbers is also incorporated.

Circle Reader Service Card 177

—*mwj*—

ANTENNA DATA CARD AVAILABLE FROM BLAINE

A helpful reference data card for antenna design and development laboratory engineers is available from Blaine Electronics, Inc., Van Nuys, Cal. Specially derived graphs and charts show in simplified form the principal sizes, distances and values of most of the required set-up data for recording antenna radiation patterns.

Commonly used systems of nomenclature, fast calculating equations and size-frequency coverage of illuminating antennas are presented in pocket-size form.

Circle Reader Service Card 178

—*mwj*—

SANDERS ISSUES BROCHURE ON NEW LONG ISLAND FACILITY

A two-color illustrated brochure describing the growth and development in the electronics industry of Sanders Associates, Inc., Nashua, N. H., and particularly of its new Plainview, Long Island, plant has been issued, according to Lloyd E. St. Jean, General Manager of Sanders' Plainview facility.

Circle Reader Service Card 179

—*mwj*—

BROCHURE DISCUSSES MEASUREMENT OF RESISTOR NOISE

Quantitative, accurate measurement of excess noise generated by current in resistors is the topic of new literature available from Quan-Tech Laboratories, Boonton, N. J.

The four-page brochure, entitled "Model 315 Resistor Noise Test Set", discusses theory relating to resistor noise, parameters in which such noise is designated, and problems in the accurate measurement of resistor noise.

A full description and specifications of the Quan-Tech Model 315 Resistor Noise Test Set is provided, as well as details of its applications in production work or in the laboratory.

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—*mwj*—

Engineers MICROWAVE TUBE

Engineers with B.S., M.S. or Ph.D. degrees in physics or related fields are invited to investigate the opportunities currently existing at the Hughes Microwave Tube Division in Southern California.

Select fields of interest include:

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- lightweight low noise amplifiers for broad band receivers,
- multielement phased array amplifiers,
- low drainage satellite communication tubes.

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Professional Employment Dept. 437

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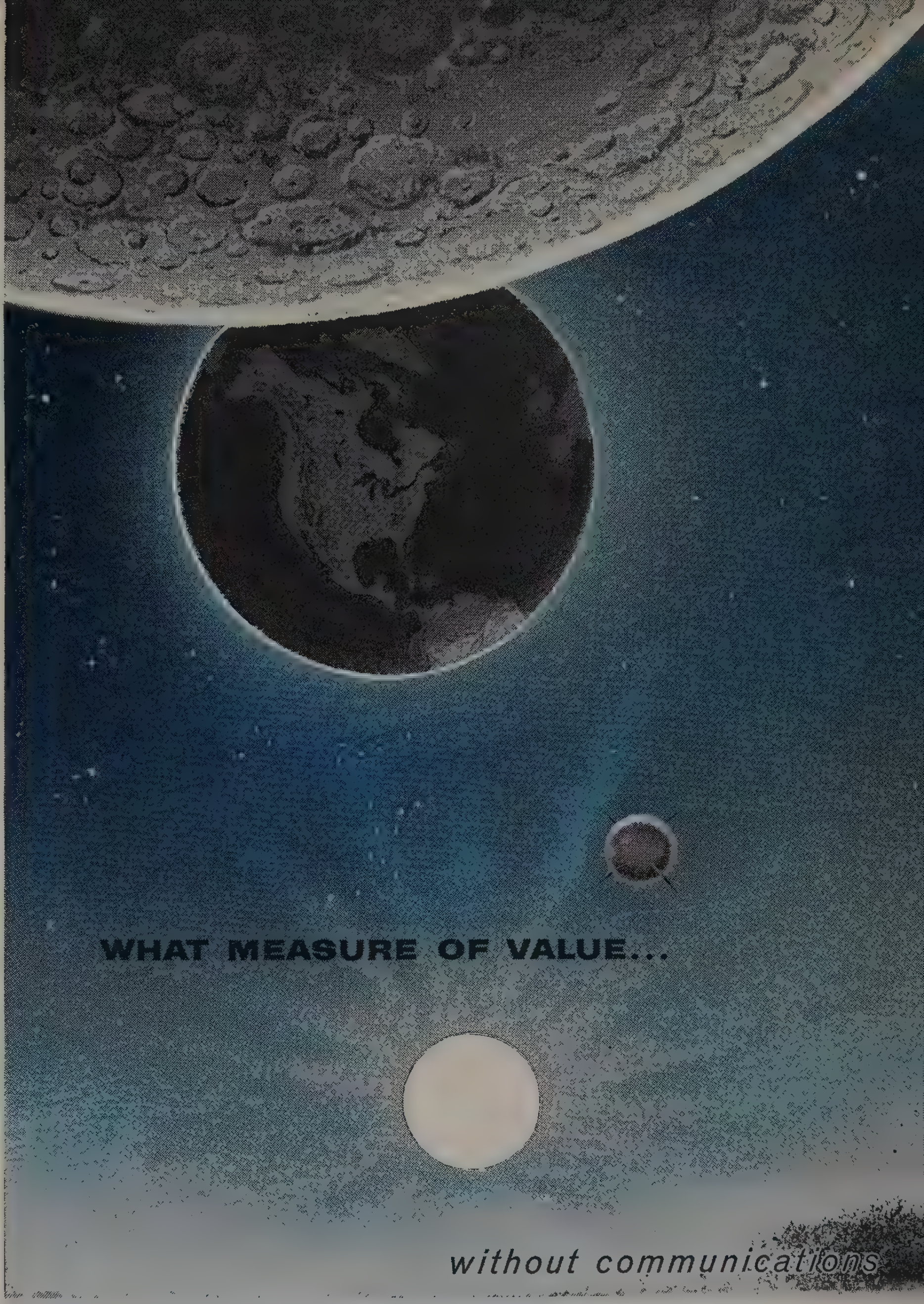

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THIS BUSINESS OF LICENSE AGREEMENTS

By JOSEPH A. BARRY

> *" BY MEANS OF A LICENSE, A PATENTEE MAY DERIVE MARKETING AND FINANCIAL BENEFITS WITHOUT ANY CAPITAL EXPENDITURE."*

I. Introduction

Patent license agreements have their inception with George Washington's issuance of the first patent (on the subject of making pot ash and pearl ash) to Samuel Hopkins of Philadelphia on July 31, 1790.

The practice of license agreements for granting rights to use claims under patents and for the purchase, sale, or exchange of industrial intellectual property was slow to gain.

The twentieth century saw the use of license agreements as a permanent economic tool of industrial management. The intrinsic value as a source of income and as an exchange of manufacturing or technical information was readily recognized.

Thoughts or opinions in the area of licensing may be easily questioned, yet are difficult to refute by authoritative citations. Conversely, affirmative or conclusive evidence on any specific point is difficult to document.

Where, formerly, the business of license agreements was strictly the prerogative of the Patent Counsel or the company law department, it now has been divided into two responsibilities — the legal aspects remaining with the lawyers and the business aspects becoming a function of management.

Licensing agreements connote many things to many businessmen:[1]

1) Patent Licenses — which may grant manufacturing rights in one or more countries and rights to use or sell for a predetermined period of time or the life of the patents.
2) Trademark Licenses — which may grant use of trademarks in individual countries to preclude the possibility of the trademark becoming common property.
3) Know how Agreements — for the sale or exchange of intellectual property.
4) Technical Assistance Agreements — which may provide for the furnishing of engineering and other assistance in the state of the art.
5) Corporate activity in world wide licensing consists of deviations from usual business practices:
    a) Local company
    b) General distributorship
    c) Exclusive distributorship
    d) Outright sale of foreign rights
    e) Use of export brokers
    f) Commission merchants
    g) Foreign local registration
    h) Local agents
6) Motivation for domestic and foreign licensing has been driven by a variety of considerations:
    a) Revenue fee or royalty income
    b) Conservation of corporate capital in dollars
    c) Penetration or expansion of foreign markets for individual product lines
    d) Preserving foreign markets for foreign manufacturing subsidiaries
    e) Exploitation of patent strength in foreign nationals

II. Scope of Licensing Activity

Divisions, subsidiaries, affiliates, or other members of corporate families, are now forced to monitor compliance with agreements and to insist on reliable royalty reporting or auditing controls. The Office of Business Economics, U. S. Department of Commerce, indicates that there are millions of dollars circulating in the license area.

With domestic, and in some cases foreign, selling prices

JOSEPH A. BARRY was educated at Harvard University where he received his AB in Economics in 1932, and he received his LLB from the Boston College Law School in 1939. He was an investigator for the United States Civil Service Commission and a sales representative for the Addressograph-Multigraph Corp.

In 1951 he joined the Magnetron Development Laboratory of the Microwave and Power Tube Division, Raytheon Company, Waltham, Mass. In 1959 when the Magnetron Development Laboratory expanded to become the Spencer Laboratory, Burlington, Mass., Mr. Barry was transferred to the division marketing organization as the Royalty Administrator. Subsequently he was appointed Manager-Marketing Administration.

Mr. Barry is a member of the American Economic Association and a lecturer on Administrative Controls and Techniques.

becoming taut, and the accelerated desire of foreign manufacturers to buy rights to developed products or process data, the scope of licensing has become world wide and may indicate a prediction of the marketing or stock position in 1965 or 1970.

The magnitude of these arrangements to improve position or penetration is highlighted in the volatile electronics industry.

According to trade disseminated information,[2] it is known that:

1) As of 30 May 1960, Raytheon Company had licensed 16 companies in 9 foreign countries and owned approximately 1,400 domestic and 950 foreign patents; it has about 600 patent applications on file.
2) International Telephone and Telegraph Corporation, its subsidiaries and divisions, owned approximately 22,400 patents in 47 countries as of 31 December 1958.
3) Westinghouse is licensed under a large (undisclosed) number of domestic and foreign patents and applications. The policy of that company is reported generally to grant non-exclusive rights. The philosophy is apparently based on management's belief that important products should not be restricted by exclusive controlling patent rights so that the manufacture of products on a licensee-competitor basis would be precluded. It should be emphasized, however, that the practice of non-exclusive licenses is the basic management philosophy of United States business.
4) General Electric Company is reputed to have approximately 1,700 unexpired domestic patents, many of which are contributing to the growth of investor interest in the stock.

The differences of opinion between the National Aeronautics and Space Administration and industry on acquiring title to patents developed under government funding research and development contracts indicates that both are evaluating their relative economic position. The Brooks Bill[3] in Congress was an attempt to reconcile the differences.

The influence of licensing arrangements and of the patent position of the American industrial economy has been weighed and defined in the O'Mahoney Reports[4]. Study No. 24, p. 29, section v, conclusions, states that "an additional, and perhaps more objective, method of evaluating the international exchange of patent rights and technical information for defense ends would be by collecting data on the numbers of license agreements in force, the types of provisions and conditions made, the extent to which such agreements are for purely commercial purposes as well as for defense production, and the changing volume of such agreements over a number of years." Although recognizing the administrative difficulties involved, the Study does point up the necessity for constant monitoring.

III. Overseas Licensing

A survey conducted by the National Industrial Conference Board, Inc., reveals that approximately 60 per cent of the respondents (240 companies) intend to expand their licensing operations, 20 per cent will be relatively constant, and 20 per cent will not increase at all and perhaps will decrease the activity. Generally, the majority of responding companies were satisfied with licensing results and felt it was only one medium of developing foreign markets. Actually only 8 per cent were reported to have entered into foreign arrangements forty years or more ago.[5]

World wide licensing in the electronics field can be measured by the recently reported completed or contemplated arrangements.[6]

1) Mitsubishi Electric Manufacturing Co., Ltd., of Tokyo is reported as planning to consummate a three (3) phase pact with Westinghouse Electric Corporation. With Westinghouse's technical know how, Mitsubishi would produce, but Westinghouse would market on a world wide basis under the Westinghouse trademark.
2) A similar arrangement is a possibility between Tokyo Shibaura Electric Co., Ltd., and General Electric Co., International, and between Matsushita Electric Industrial Co., Ltd., of Japan and Nash-Kelvinator Corporation.
3) Last summer Compagnie Generale de Telegraphie Sans Fil of Paris launched into a joint European program with Thompson Ramo Wooldridge, Inc., of California and Intertechnique of France.
4) Raytheon Company of Waltham, Mass., recently secured Japan's Foreign Capital Council's approval for a license agreement for Oki Electric Industry Co., Ltd., to manufacture a milliwave magnetron.
5) The Foreign Capital Council of Japan officially approved an agreement on the sale of intellectual property by Sperry Rand Corp., New York, to Nippon Electric Co., Ltd., the Koke Kogyo Corp., the Hitachi Ltd., and Toshiba Ltd., all of Tokyo.
6) Eitel-McCullough, Inc., of California, is reported as having entered into an exchange of manufacturing rights and technical know how with English Electric Valve Co., Ltd., of England.
7) Raytheon Company signed a broad license agreement granting certain patent rights on the HAWK missile to the Societe Europeanne de Teleguidage (SETEL). Raytheon will also supply important technical assistance in establishing production lines for the manufacturers: Thomson-Houston, France; Finemeccanica, Italy; Telefunken, Germany; Ateliers de Construction Electrique de Charleroi, Belgium; and Philips, The Netherlands.
8) Radio Corporation of America and the Instituto per la Riconstruzione Industriale, the Italian Government controlled agency, entered into an agreement whereby I.R.I. will reportedly invest $25,000,000 initial funding, and RCA will furnish technical know how in the same areas of manufacturing, management and marketing.

For ten years, RCA may enjoy a special license arrangement strength against such as International Telephone and Telegraph Corporation, Admiral Corporation, Sylvania Electric Products, Inc., a subsidiary of

General Telephone and Telegraph Corporation, and such foreign giants as Telefunken, Siemens and Halske, N.V. Philips Gleoielampenfabrieken — all European Common Market competitors.

Raytheon, Eitel-McCullough, General Electric, and Litton Industries, it is claimed, should be in a strong competitive position in the new ECM.

The USSR is tempting British electronics manufacturers to secure license rights. One plan with Twentieth Century Electronics Ltd., England, would be sending English engineers and technicians to the Soviet Union to install a manufacturing plant and train Russian technicians at English plants.

The growth of foreign licensing — the problems of servicing, monitoring, and processing royalty and know how income — recently influenced the establishment in Paris of a new affiliate of GE — the International General Electric, which is said to be currently mainly concerned with collecting royalties from French users of GE patents and for technical assistance involved in the effective use of such patents.

The expediency of foreign licensing is influenced by the expense of foreign filing, the time consumed in negotiating, price considerations, capital dollar output, equity licensing, political or investment climate.

IV. Domestic Influences

At home, mergers, consolidations, acquisitions pinpoint the order of magnitude in the procuring of rights to patents owned by smaller companies.

Electro-Tec Corp., New Jersey, is cited by Mr. George J. Pandapas, President, as having acquired Lambros Precious Metal Co., New York, primarily to bring into the ETC patent portfolio another substantial area of coverage.[6]

Litton Industries claims it has purchased a majority interest in Fritz Hellige and Co., Freiburg-im-Breisgan, Germany. One assumption that might be made is that the ownership of Hellige patents and the acquisition of other license rights may have been a weighty consideration.

The acquisition of patents and the inherent dangers of control of patent pools are matters which are being carefully scrutinized because of possible U. S. antitrust law violations.

V. Importance of Royalty Administration

Many U. S. corporations are not yet fully realizing on the intrinsic value of their intellectual property.

Convair, however, is said to be currently licensing processes and products to approximately sixty firms for manufacture. These are being given rights to manufacture items which have been described as by-products of normal Convair operations and which Convair feels can be better exploited by interests outside.

The importance of income is emphasized by the monitoring and auditing techniques being developed to implement the audit right in many licenses. The collection of royalties is an administrative problem which each licensor must follow closely. Many companies which have experienced volatile growth now realize that royalties and fees do not automatically flow into a home office. The attention which is being given the loss of legitimate license income is commensurate with the effort of industry to protect its processes and products.

The frequency of patent infringement and antitrust suits involving control of groups of patents, as well as the restriction of free enterprise, is reflecting itself daily,

RCA and Philco are battling out an antitrust suit in the Federal Courts at Philadelphia. Philco (plaintiff) charged that RCA's former president engaged in "concealment" in influencing GE not to sign a cross-license agreement with Philco.

Philco, in turn, asked the court to declare the paten pool allegedly controlled by RCA "to be an illega media".

Suits against the U. S. Government are occurring. Cannon Electric Co., California, recently is reported as entering suit against government for patent infringement. H was charged that the government used Cannon's paten claims in the subminiature connector area. Cannon aske that the subject patent be declared valid, that it was in fact infringed, and asked for a complete accounting an payment of reasonable royalties.

VI. Licensing is Business

It has become necessary for management to fight fo each dollar of non-operating income, particularly royalty and fees. It has, likewise, become urgent that managemen plan and schedule license arrangements to conform with long range financial objectives.

The average corporation finds that the cost of maintaining a strong patent and trademark position in all possible markets is financially impossible. By means of a license, a patentee may derive marketing and financia benefits without any capital expenditure.

A foreign or a strong domestic license is a consideratio which market analysts no longer are able to ignore.

Since the International Convention for the Protectio of Industrial Property came into being in July 1884, the influence of the economic stability and aggressive marketing practices of American industry has grown until in 1961 the business of licenses is a strategic and stable management tool.

Footnotes

1. Paper by Lawrence J. Eckstrom, Attorney, Baker, McKenzi and High Tower, New York; reported by Internationa Management Association, Special Report No. 1
2. Moody's Industrial Manual, 1959 and 1960 editions
3. HR 12,049
4. "The Patent System: Its Economic And Social Basis" Study No. 26, and "Patent and Technical Informatio Agreements", Study No. 24, Study of the Subcommittee on Patents, Trademarks, and Copyrights of the Committee on the Judiciary, U. S. Senate, 86th Congress, 2nd Session pursuant to S. Rev. 240
5. "Foreign Licensing Agreements", Studies In Business Policy, No. 86, National Industrial Conference Board, Inc.
6. Electronic News, Fairchild Publications, 1960

Bibliography

"Licensing — A Road To Profit", Steel, Vol. 142, February 1958.

Weeks, E., "Royalties In Russia", Atlantic Monthly, Vol 205, January, 1960.

Gray, A. W., "Patent Licenses — Good Buyers Negotiate Flexible Conditions", Purchasing, Vol. 44, February, 1958.

"Licensing Abroad", a compilation of articles from many sources, U. S. Department of Commerce, Foreign, 1959.

Hastings, G. S., "Building Profits On Outside Inventions" Dun's Review And Modern Industry, Vol. 71, June, 1958.

"Time To Take A Second Look At Foreign Patents", Chemica Week, Vol. 84, March, 1959.

"Of Rubles And Royalties", Saturday Review, Vol. 42, September, 1959.

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9	10	11	12	13	14	15	16	105	106	107	108	109	110	111	112
17	18	19	20	21	22	23	24	113	114	115	116	117	118	119	120
25	26	27	28	29	30	31	32	121	122	123	124	125	126	127	128
33	34	35	36	37	38	39	40	129	130	131	132	133	134	135	136
41	42	43	44	45	46	47	48	137	138	139	140	141	142	143	144
49	50	51	52	53	54	55	56	145	146	147	148	149	150	151	152
57	58	59	60	61	62	63	64	153	154	155	156	157	158	159	160
65	66	67	68	69	70	71	72	161	162	163	164	165	166	167	168
73	74	75	76	77	78	79	80	169	170	171	172	173	174	175	176
81	82	83	84	85	86	87	88	177	178	179	180	181	182	183	184
89	90	91	92	93	94	95	96								

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33 34 35 36 37 38 39 40 129 130 131 132 133 134 135 136
41 42 43 44 45 46 47 48 137 138 139 140 141 142 143 144
49 50 51 52 53 54 55 56 145 146 147 148 149 150 151 152
57 58 59 60 61 62 63 64 153 154 155 156 157 158 159 160
65 66 67 68 69 70 71 72 161 162 163 164 165 166 167 168
73 74 75 76 77 78 79 80 169 170 171 172 173 174 175 176
81 82 83 84 85 86 87 88 177 178 179 180 181 182 183 184
89 90 91 92 93 94 95 96

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1 2 3 4 5 6 7 8 97 98 99 100 101 102 103 104
9 10 11 12 13 14 15 16 105 106 107 108 109 110 111 112
17 18 19 20 21 22 23 24 113 114 115 116 117 118 119 120
25 26 27 28 29 30 31 32 121 122 123 124 125 126 127 128
33 34 35 36 37 38 39 40 129 130 131 132 133 134 135 136
41 42 43 44 45 46 47 48 137 138 139 140 141 142 143 144
49 50 51 52 53 54 55 56 145 146 147 148 149 150 151 152
57 58 59 60 61 62 63 64 153 154 155 156 157 158 159 160
65 66 67 68 69 70 71 72 161 162 163 164 165 166 167 168
73 74 75 76 77 78 79 80 169 170 171 172 173 174 175 176
81 82 83 84 85 86 87 88 177 178 179 180 181 182 183 184
89 90 91 92 93 94 95 96

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Complete this section if you are principally engaged in COMPONENTS: 0-29

0-65 ☐ **Antennas**
1-65 ☐ Large 3-65 ☐ Small (Under 12')
5-65 ☐ Communication 0-66 ☐ Tropo Scatter
7-65 ☐ Tracking 1-66 ☐ Airborne
9-65 ☐ Detection 3-66 ☐ Other ________ **Specify**

0-67 ☐ **Instruments** ________ **Specify**

7-67 ☐ **Tubes** 7-68 ☐ Storage
9-67 ☐ Planar 9-68 ☐ Gaseous Discharge
0-68 ☐ Passive devices 0-69 ☐ Magnetron
1-68 ☐ Klystron 1-69 ☐ BWO
High or low power 3-69 ☐ TWT
3-68 ☐ 5-68 ☐ 5-69 ☐ Other ________ **Specify**

1-70 ☐ **Solid State** 7-71 ☐ Masers
3-70 ☐ Amplifiers 9-71 ☐ Diodes
5-70 ☐ Transistors 0-72 ☐ Ferrimagnetics
7-70 ☐ Paramagnetic 1-72 ☐ Parametrics
9-70 ☐ Thermoelectric 3-72 ☐ Crystals
0-71 ☐ Ferrites ________ 5-72 ☐ Infrared
Type
7-72 ☐ Other ________
specify
3-73 ☐ Transmission Lines
5-73 ☐ Transitions
7-73 ☐ Coaxial
9-73 ☐ Waveguide Adapters

0-74 ☐ **Small Components**
1-74 ☐ Bolometers 3-75 ☐ Filters
3-74 ☐ Holders & Mounts 5-75 ☐ Attenuators
5-74 ☐ Horns 7-75 ☐ Limiters
7-74 ☐ Hybrid Junctions 9-75 ☐ Diplexers
9-74 ☐ Isolators 0-76 ☐ Terminations
0-75 ☐ Gyrators 1-76 ☐ Other ________ **Specify**
1-75 ☐ Switches
9-76 ☐ **Waveguides**
0-77 ☐ Rigid 1-77 ☐ Flexible
3-77 ☐ **Windows**

If you are principally engaged in component activity, Tubes, Antennas, Hardware, etc.:

1. Is your principal activity to develop and/or manufacture components for direct sale? ——Yes ——No
2. Is your principal activity to produce and/or develop components for in-company systems manufacture?
——— Yes ——— No
3. If your answer to Question #2 is "Yes" please specify system or field of activity.
____
____

Important! Fold (Do not tear)

Complete this section if you are PRINCIPALLY engaged in any activities listed below. 0-33

0-78 ☐ Millimeter ________ **Specify**
7-78 ☐ Infrared ________ **Specify**
3-79 ☐ Magnetics ________ **Specify**
9-79 ☐ Cryogenics ________ **Specify**
3-86 ☐ **Plastics**
5-86 ☐ **Radomes** 0-87 ☐ Dielectrics
7-86 ☐ Insulation 1-87 ☐ Absorbers
9-86 ☐ Packaging 3-87 ☐ Others ________
5-87 ☐ **Materials** 0-88 ☐ Metal Production
7-87 ☐ Garnets
9-87 ☐ Germanium 1-88 ☐ Ferrites
3-88 ☐ Arsenide
5-88 ☐ Inter Metallic Compounds
7-88 ☐ Rubies
9-88 ☐ Other ________

0-89 ☐ **Plasma**
1-89 ☐ Ionized gases
3-89 ☐ Other ________
5-89 ☐ Spectroscopy
7-89 ☐ Optics
9-89 ☐ **Nuclear**
0-90 ☐ Linear Accelerator
1-90 ☐ Cyclotron
3-90 ☐ Other ________
5-90 ☐ Atomic Beams
7-90 ☐ Hermetic Seals
9-90 ☐ Other ________
____
____

Please identify your activity as precisely as possible if not listed in above area.

If you are principally engaged in component activity:

1. Is your principal activity to develop and/or manufacture components for direct sale?
________Yes ________No
2. Is your principal activity to produce and/or develop components for in-company systems manufacture?
________Yes ________No
3. If your answer to Question #2 is "Yes" please specify system or field of activity. ________

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52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	86	87	88	89

1 ☐ Name ______________________ Full Title ______________
2 ☐ **First** **Middle Initial** **Last**

3 ☐ Company ______________________

4 ☐ Department ______________________

5 ☐ Co. Address ______________________
Street **City** **Zone** **State**

Address to which you wish the journal sent—home address preferable

____

____

If change of address, place old address below and answer all questions completely.

Please check the areas below in which you are PRINCIPALLY engaged.

☐ Research and Development

☐ Design

☐ Executive

☐ Applications

☐ Purchasing

☐ Production

☐ Education

☐ **Sales**

☐ Other

☐ **Manufacturers Rep**

Specify if you are working for a Civil ☐ or Military ☐ Agency.

Complete this section if you are PRINCIPALLY engaged in SYSTEMS. 0-25

0-26 ☐ Radar ______________________
Specific Activity

1-27 ☐ Missiles ______________________
Specific Activity

3-28 ☐ Tracking 5-28 ☐ Guidance

7-28 ☐ Airborne ______________________
Specific Activity

3-30 ☐ Ground Support ______________________
Specific Activity

0-31 ☐ ASW ______________________
Specific Activity

7-31 ☐ Telemetering ______________________
Specific Activity

1-32 ☐ Radiometry ______________________
Specific Activity

9-32 ☐ Data Processing ______________________
Specific Activity

5-34 ☐ Radio Astronomy ______________________
Specific Activity

1-41 ☐ Countermeasures
3-41 ☐ Point to point Relay Links
5-41 ☐ Detection Systems
7-41 ☐ Infrared 9-41 ☐ Other ______________
Type
5-42 ☐ Commercial MW Relay User
7-42 ☐ Industry served ______________

1-43 ☐ **Sonar**
3-43 ☐ Ultrasonics
5-43 ☐ Other________
1-44 ☐ **Communications**
3-44 ☐ UHF, VHF
5-44 ☐ Space Communications
7-44 ☐ Radio
9-44 ☐ Television
0-45 ☐ Receivers
1-45 ☐ Transmitters
3-45 ☐ Other ______________
0-63 ☐ **Subsystems**
1-63 ☐ Power Supplies
3-63 ☐ Modulators
5-63 ☐ Receivers
7-63 ☐ Other ______________

Please specify other type of system or subsystem and your particular duties or relation to it on lines below.

____

____

____

____

Name ______________________ **Company** ______________________

Your title ______________________ **No. Empl. in your Co.** ______________

Would a microwave engineering handbook and catalog purchasing guide be useful in your research and development or design work? ________Yes ________No

Estimate the number of engineers working in microwave activities.

In your company ______________ In your department ______________

Do you make equipment purchase recommendations? ______________________

If yes, what types of equipment? ______________________

____

In what research project (s) are you now involved? ______________________

____

What new equipment or device do you feel needs development? ______________________

____

In what type of activity is your company principally engaged?

☐ Systems ☐ Components ☐ Other

BANDWIDTH WITH HIGH EFFICIENCY

HIGHEST POWER TWT

3 MEGAWATTS AT C-BAND

VA-126 TWT
3 MW Peak
5 KW Average
5.4 to 5.9 kMc

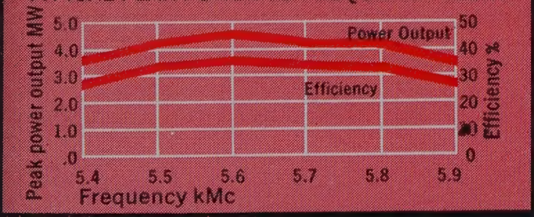
Varian Associates' new VA-126 pulse power amplifier traveling wave tube is particularly well-suited for advanced coherent radar systems employing frequency agility. With high gain and high efficiency over the full bandwidth, the tube offers a new standard in transmitter performance.

The VA-126 produces 3 MW peak and 5 KW average power, from 5.4 to 5.9 kMc. Gain, 35db; efficiency, 30%. Self-centering in electromagnet. Liquid cooled.

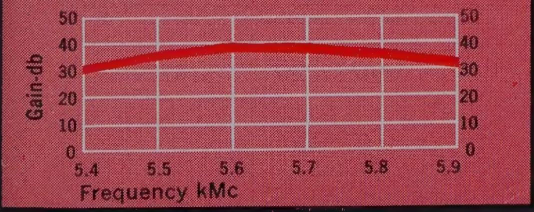
The VA-126 has 500 Mc bandwidth and excellent phase stability. These are desirable characteristics for pulse-to-pulse frequency changes, phase coding, chirping (frequency changes within the pulse), and electronically-steerable antenna arrays.

Varian's unrivaled capability in the development of advanced microwave tubes is at your service. For further data on the VA-126, write Tube Div.

TYPICAL PEAK POWER VS. FREQUENCY-130KV



TYPICAL GAIN VS. FREQUENCY-130KV



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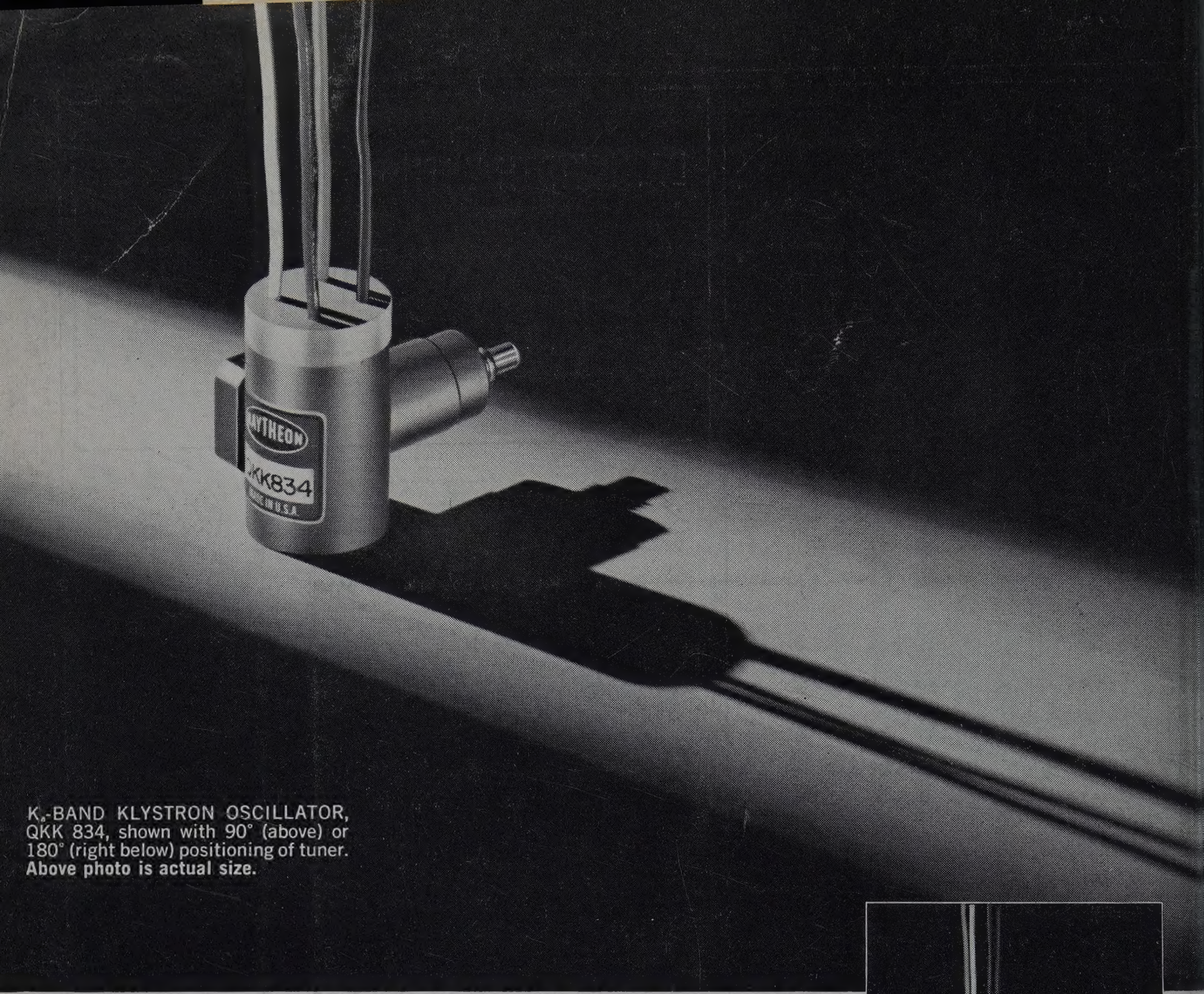
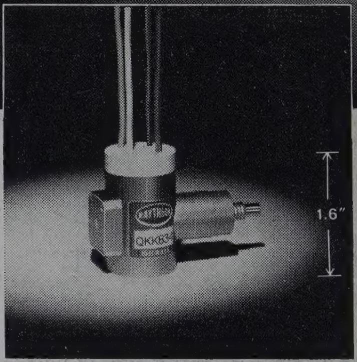


K$_a$-BAND KLYSTRON OSCILLATOR, QKK 834, shown with 90° (above) or 180° (right below) positioning of tuner. **Above photo is actual size.**



New klystrons hold characteristics in grueling aerospace environments

K$_a$- and K-band tubes are tunable from 34.0 – 35.6 and 23.5 – 24.5 kMc

Now, Raytheon combines the advantages of small size, extreme ruggedness, thermal stability, and smooth wide-range tunability in a 20mW reflex klystron.

The new QKK 834 for K$_a$ band and QKK 923 for K band are all ceramic and metal tubes with typical electronic tuning range of 110 Mc. The tuner, utilizing a sapphire rod, can be specified for positioning anywhere on the circumference of the resonator at least 90 degrees from output flange (see illustrations above). Write today for detailed technical data or application service to Microwave & Power Tube Division, Raytheon Company, Waltham 54, Massachusetts. In Canada: Waterloo, Ontario.

QKK 834, QKK 923 –
GENERAL CHARACTERISTICS

Power Output	20 mW (nominal)
Frequency	34-35.6*; 23.5-24.5† kMc
Resonator Voltage	400 V
Reflector Voltage Range	—65 to —175V
Temperature Coefficient	± 0.5 Mc/°C
Cooling	convection (no blower needed)
Overall Dimensions	1 5/8 x 1 1/16 x 2 in.*

*QKK 834 †QKK 923

RAYTHEON COMPANY

MICROWAVE AND POWER TUBE DIVISION

RAYTHEON